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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

THIRD ANNUAL REPORT
OF THE
RECLAMATION SERVICE

1903-4

[SECOND EDITION]

F. H. NEWELL
Chief Engineer

WASHINGTON
GOVERNMENT PRINTING OFFICE
1905

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LETTERS OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., September 15, 1905.

SIR: I have the honor to transmit herewith the second edition of the Third Annual Report of the Reclamation Service, which has been prepared in accordance with joint resolution No. 27, Fifty-eighth Congress, third session, approved March 3, 1905 (33 Stat. L., p. 1285).

This report supplements the information given in the First Annual Report of the Reclamation Service (H. Doc. No. 79, 57th Cong., 2d sess.), in the Second Annual Report of the Reclamation Service (H. Doc. No. 44, 58th Cong., 2d sess.), and in the Third Annual Report of the Reclamation Service (H. Doc. No. 28, 58th Cong., 3d sess.). The text of this report is substantially the same as that of the third annual report, but it has been modified in places as the result of office work upon the data obtained during the field season. There have also been inserted the illustrations prepared after the close of the field season.

This report shows that examinations and surveys, as required by law, have been carried on throughout the arid regions, and that construction has been begun and has progressed rapidly wherever the surveys have demonstrated the practicability of a project. At the beginning of the last session of Congress work had been begun and was being carried forward actively in Nevada and Arizona, and contractors were entering upon heavy construction in Idaho, Colorado, and New Mexico. In several other States and Territories operations had reached a point where specifications had been drawn and advertisements for bids awaited only the removal of certain legal obstacles or the termination of delays on the part of local organizations or individuals. The work accomplished since December 1, 1904, will be described in the report to be submitted to Congress at the beginning of the regular session in December, 1905.

Since the reclamation act has been in effect it has been put to the test in various ways. The organization for carrying it into effect has been largely perfected, and precedents have been established along the most approved lines. The general allotment of funds has been carefully studied from the broad standpoint of the benefits to be derived by the country as a whole, and most of the chief problems have been solved. It now remains to put into execution, economically and effectively, the plans which have been determined upon.

Nearly all the projects under consideration are relatively large and involve engineering difficulties or have complications arising from private or vested interests. Nowhere is it possible to go forward untrammeled. Practically every irrigation enterprise has at some time been taken up by individuals or corporations, and been dropped for good reason. The engineers of the Reclamation Service are under the necessity of attacking the problems whose solution others have found difficult or impossible, and must study ways of overcoming various obstacles, both physical and legal; hence unavoidable delays and occasional disappointments have arisen. On the whole, however, the progress has been as rapid as is consistent with care and accuracy, and the thoroughness of the work has been commended by persons competent to judge of it.

Special attention has been given to the economies of the work—to recording full information concerning costs and to keeping all operations on a strictly business basis. In the conduct of work at points as numerous and as scattered as those at which the Reclamation Service is operating it is impossible to pursue methods which are practicable in the case of a single establishment or of a continuous line of railway; but, taking into account the wide distribution of operations and the initiative and judgment which must be left to the engineers, it is belived that the results are highly satisfactory.

The reclamation act has been found to embody the most essential features necessary to good administration and at the same time to be sufficiently elastic to permit adaption to local circumstances.

It is believed that work can be pushed forward in the future with accelerating speed as the results of the previous investigations become available.

Very respectfully,

H. C. RIZER,
Acting Director.

The SECRETARY OF THE INTERIOR.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
RECLAMATION SERVICE,
Washington, D. C., September 2, 1905.

SIR: I transmit herewith the manuscript of the second and revised edition of the Third Annual Report of the Reclamation Service. The text is essentially the same as that in the report which was submitted at the beginning of the third session of the Fifty-eighth Congress, but some sections have been rewritten and some of the data have been revised in accordance with the computations made after the close of the field season. The manuscript is accompanied by a number of plates, which could not be prepared in time for the regular report.

Very respectfully,

F. H. Newell,
Chief Engineer.

Hon. Charles D. Walcott,
Director United States Geological Survey.

THIRD ANNUAL REPORT

OF THE

RECLAMATION SERVICE.

[SECOND EDITION.]

F. H. NEWELL, *Chief Engineer.*

GENERAL DISCUSSION, ORGANIZATION, AND SUMMARY OF WORK.

The First Annual Report of the Reclamation Service, dated November 29, 1902, gave a brief description of the location and condition of the arid public lands and summarized the history of the national irrigation movement, the laws recognizing irrigation, and the conditions of the work of reclamation in the various States and Territories.

The Second Annual Report took up the general discussion of the reclamation law, reciting decisions of the Secretary of the Interior concerning it, and described in detail the work begun in the various States and Territories, showing in particular what had been accomplished in 1903.

In this, the Third Annual Report, is given a continuation of the description of the work begun; in particular, an exhibit is made of the operations carried on during the greater part of the calender year 1904. This matter is preceded by a general discussion of the reclamation law and of the general questions of policy or practice which have arisen.

RECLAMATION LAW.

For convenience of reference there is here inserted the full text of the reclamation act. Much of the discussion concerning the operations under this act and the effect of it on the future development of the West has been made with little reference to the law itself, and it seems advisable to frequently call attention to the letter and the spirit of the act in order to prevent misconception of the objects and purposes of the Reclamation Service.

AN ACT appropriating the receipts from the sale and disposal of public lands in certain States and Territories to the construction of irrigation works for the reclamation of arid lands.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That all moneys rceived from the sale and disposal of public lands in Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Utah, Washington, and Wyoming, beginning with the fiscal year ending June thirtieth, nineteen hundred and one, including the surplus of fees and commissions in excess of allowances to registers and receivers, and excepting the five per centum of the proceeds of the sales of public lands in the above States set aside by law for educational and other purposes, shall be, and the same are hereby, reserved, set aside, and appropriated as a special fund in the Treasury to be known as the "reclamation fund," to be used in the examination and survey for and the construction and maintenance of irrigation works for the storage, diversion, and development of waters for the reclamation of arid and semiarid lands in the said States and Territories, and for the payment of all other expenditures provided for in this act: *Provided,* That in case the receipts from the sale and disposal of public lands other than those realized from the sale and disposal of lands referred to in this section are insufficient to meet the requirements for the support of agricultural colleges in the several States and Territories, under the act of August thirtieth, eighteen hundred and ninety, entitled "An act to apply a portion of the proceeds of the public lands to the more complete endowment and support of the colleges for the benefit of agriculture and the mechanic arts, established under the provisions of an act of Congress approved July second, eighteen hundred and sixty-two," the deficiency, if any, in the sum necessary for the support of the said colleges shall be provided for from any moneys in the Treasury not otherwise appropriated .

SEC. 2. That the Secretary of the Interior is hereby authorized and directed to make examinations and surveys for, and to locate and construct, as herein provided, irrigation works for the storage, diversion, and development of waters, including artesian wells, and to report to Congress at the beginning of each regular session as to the results of such examinations and surveys, giving estimates of cost of all contemplated works, the quantity and location of the lands which can be irrigated therefrom, and all facts relative to the practicability of each irrigation project; also the cost of works in process of construction as well as of those which have been completed.

SEC. 3. That the Secretary of the Interior shall, before giving the public notice provided for in section four of this act, withdraw from public entry the lands required for any irrigation works contemplated under the provisions of this act, and shall restore to public entry any of the lands so withdrawn when, in his judgment, such lands are not required for the purposes of this act; and the Secretary of the Interior is hereby authorized, at or immediately prior to the time of beginning the surveys for any contemplated irrigation works, to withdraw from entry, except under the homestead laws, any public lands believed to be susceptible of irrigation from said works: *Provided,* That all lands entered and entries made under the homestead laws within areas so withdrawn during such withdrawal shall be subject to all the provisions, limitations, charges, terms, and conditions of this act; that said surveys shall be prosecuted diligently to completion, and upon the completion thereof, and of the necessary maps, plans, and estimates of cost, the Secretary of the Interior shall determine whether or not said project is practicable and advisable, and if determined to be impracticable or unadvisable he shall thereupon restore said lands to entry; that public lands which it is proposed to irrigate by means of any contemplated works shall be subject to entry only under the provisions of the homestead laws in tracts of not less than forty nor more than one hundred and sixty acres, and shall be subject to the limitations, charges, terms, and conditions herein provided: *Provided*, That the commutation provisions of the homestead laws shall not apply to entries made under this act.

SEC. 4. That upon the determination by the Secretary of the Interior that any irrigation project is practicable, he may cause to be let contracts for the construction of the same, in such portions or sections as it may be practicable to construct and complete as parts of the whole project, providing the necessary funds for such portions or sections are available in the reclamation fund, and thereupon he shall give public notice of the lands irrigable under such project, and limit of area per entry, which limit shall represent the acreage which, in the opinion of the Secretary, may be reasonably required for the support of a family upon the lands in question; also of the charges which shall be made per acre upon the said entries, and upon lands in private ownership which may be irrigated by the waters of the said irrigation project, and the number of annual installments, not exceeding ten, in which such charges shall be paid and the time when such payments shall commence. The said charges shall be determined with a view of returning to the reclamation fund the estimated cost of construction of the project, and shall be apportioned equitably: *Provided*, That in all construction work eight hours shall constitute a day's work, and no Mongolian labor shall be employed thereon.

SEC. 5. That the entryman upon lands to be irrigated by such works shall, in addition to compliance with the homestead laws, reclaim at least one-half of the total irrigable area of his entry for agricultural purposes, and before receiving patent for the lands covered by his entry shall pay to the Government the charges apportioned against such tract, as provided in section four. No right to the use of water for land in private ownership shall be sold for a tract exceeding one hundred and sixty acres to any one landowner, and no such sale shall be made to any landowner unless he be an actual bona fide resident on such land, or occupant thereof residing in the neighborhood of said land, and no such right shall permanently attach until all payments therefor are made. The annual installments shall be paid to the receiver of the local land office of the district in which the land is situated, and a failure to make any two payments when due shall render the entry subject to cancellation, with the forfeiture of all rights under this act, as well as of any moneys already paid thereon. All moneys received from the above sources shall be paid into the reclamation fund. Registers and receivers shall be allowed the usual commissions on all moneys paid for lands entered under this act.

SEC. 6. That the Secretary of the Interior is hereby authorized and directed to use the reclamation fund for the operation and maintenance of all reservoirs and irrigation works constructed under the provisions of this act: *Provided*, That when the payments required by this act are made for the major portion of the lands irrigated from the waters of any of the works herein provided for, then the management and operation of such irrigation works shall pass to the owners of the lands irrigated thereby, to be maintained at their expense under such form of organization and under such rules and regulations as may be acceptable to the Secretary of the Interior: *Provided*, That the title to and the management and operation of the reservoirs and the works necessary for their protection and operation shall remain in the Government until otherwise provided by Congress.

SEC. 7. That where in carrying out the provisions of this act it becomes necessary to acquire any rights or property, the Secretary of the Interior is hereby authorized to acquire the same for the United States by purchase or by condemnation under judicial process, and to pay from the reclamation fund the sums which may be needed for that purpose, and it shall be the duty of the Attorney-General of the United States upon every application of the Secretary of the Interior, under this act, to cause proceedings to be commenced for condemnation within thirty days from the receipt of the application at the Department of Justice.

SEC. 8. That nothing in this act shall be construed as affecting or intended to affect or to in any way interfere with the laws of any State or Territory relating to the control, appropriation, use, or distribution of water used in irrigation, or any vested right acquired thereunder, and the Secretary of the Interior, in carrying out the provisions of this act, shall proceed in conformity with such laws, and nothing herein shall in any way affect any right of any State or of the Federal Government or of any landowner, appropriator, or user of water in, to, or from any interstate stream or the waters thereof: *Provided*, That the right to the use of water acquired under the provisions of this act shall be appurtenant to the land irrigated, and beneficial use shall be the basis, the measure, and the limit of the right.

SEC. 9. That it is hereby declared to be the duty of the Secretary of the Interior in carrying out the provisions of this act, so far as the same may be practicable and subject to the existence of feasible irrigation projects, to expend the major portion of the funds arising from the sale of public lands within each State and Territory hereinbefore named for the benefit of arid and semiarid lands within the limits of such State or Territory: *Provided*, That the Secretary may temporarily use such portion of said funds for the benefit of arid or semiarid lands in any particular State or Territory hereinbefore named as he may deem advisable, but when so used the excess shall be restored to the fund as soon as practicable, to the end that ultimately, and in any event, within each ten-year period after the passage of this act, the expenditures for the benefit of the said States and Territories shall be equalized according to the proportions and subject to the conditions as to practicability and feasibiliy aforesaid.

SEC. 10. That the Secretary of the Interior is hereby authorized to perform any and all acts and to make such rules and regulations as may be necessary and proper for the purpose of carrying the provisions of this act into full force and effect.

Approved, June 17, 1902.

DETAILS OF THE LAW.

The law has been in operation less than two and one-half years, but in that time a great many questions have arisen concerning details which could not have been anticipated in the law itself. Most of these have been satisfactorily settled, and good precedents have been established on points where discretion has been left to executive officers.

FUNDS FOR RECLAMATION.

The fund set aside by the act, as is shown by section 1, is derived from the sale and disposal of public lands in 13 States and 3 Territories. Certain deductions are made, but after allowing for them the available funds are shown by the following table, giving the amounts to the credit of the funds from each State and Territory:

Reclamation fund for years 1901–1904, inclusive.

State or Territory.	1901.	1902.	1903.	1904.	Aggregate.
Arizona	$42,586.16	$39,187.35	$48,360.20	63,266.02	193,399.73
California	205,030.40	298,240.36	839,221.40	482,077.16	1,824,569.32
Colorado	254,889.88	374,105.13	549,812.89	472,379.85	1,651,187.75
Idaho	206,645.36	300,803.27	650,331.95	493,697.20	1,651,477.78
Kansas	20,188.78	28,946.94	27,836.50	32,478.56	109,450.78
Montana	367,342.31	405,035.49	558,071.49	466,708.41	1,797,157.70
Nebraska	102,963.24	132,234.94	138,728.70	118,786.59	492,713.47
Nevada	9,183.47	14,230.61	14,136.76	16,210.58	53,761.42
New Mexico	75,203.06	72,034.60	154,265.49	86,602.58	388,105.73
North Dakota	449,474.96	778,021.35	1,244,916.47	1,160,386.68	3,632,799.46
Oklahoma	370,464.93	638,330.44	864,766.83	763,511.39	2,637,073.59
Oregon	364,988.62	545,972.44	1,896,970.68	1,350,651.21	4,158,582.95
South Dakota	113,274.20	194,288.17	248,696.14	249,225.28	805,483.79
Utah	98,416.00	48,408.38	88,872.38	48,716.82	284,413.58
Washington	257,180.95	536,907.82	1,109,299.54	696,271.34	2,599,659.65
Wyoming	206,989.59	178,773.24	279,709.18	325,283.92	990,755.93
Total	3,144,821.91	4,585,520.53	8,713,996.60	6,826,253.59	23,270,592.63

EXAMINATIONS AND SURVEYS.

Section 2 of the act directs the Secretary of the Interior to make examinations and surveys and to construct irrigation works. In order to carry on these operations there has been gradually created what is known as the "Reclamation Service," for which competent men have been selected through civil-service examination. The organization of this corps of engineers has been a matter of evolution as necessitated by the circumstances, attempt being made to secure the largest efficiency irrespective of other considerations.

Section 2 also directs that a report be made giving results of examinations, surveys, and estimates of cost and all other facts relative to the practicability of each irrigation project. These matters of cost and practicability are fundamental, and great care is being given to checking up the preliminary estimates against the facts obtained by actual experience as the work progresses.

WITHDRAWAL OF LANDS.

Section 3 provides for making temporary or permanent withdrawals of lands pending survey or for the construction of works. In each area under examination bodies of land have been withdrawn for one or the other purpose. Two forms of withdrawal are specified; the first absolute, the second subject to limitations. Under the first form of withdrawal the lands indicated are held by the Government from all forms of entry and settlement. In this manner areas needed for various kinds of structures or works are set aside and can not be filed upon or title acquired under any of the various land laws.

Under the second form of withdrawal the lands are subject to entry under the homestead laws without commutation provisions. Considerable tracts containing irrigable lands are thus set aside, and these may be entered by settlers who have not used their homestead rights. In making entries, however, the homesteader becomes subject to various limitations and charges, and the size of his entry may be cut down from 160 to 40 acres. This condition is giving rise to more or less confusion from the fact that under the letter of the law and decisions from the Secretary's office the public lands which may be irrigated are first taken up in tracts of 160 acres, and later, when these are cut down to 80 acres, or even 40 acres, there is uncertainty or controversy regarding the portion of the 160 acres which shall be allotted to the entryman. Many of these controversies could be avoided if it were possible under the law to limit the entry to 40 or 80 acres at the time when it was known that such limitation should be put upon the land. As the matter now stands, this announcement can not be properly made until the contracts for the construction of work have been let.

As a rule all of the irrigable public land which is being surveyed under each project is entered at once by the public in 160-acre tracts. It is generally known in advance that the farm unit will be reduced, but the entrymen prefer to enter all of the land possible and take the chances that the necessary relinquishment may be in some manner profitable to themselves.

CONSTRUCTION AND CHARGES.

Section 4 provides for the letting of contracts for construction work and authorizes the Secretary of the Interior to give public notice of the lands irrigable and the limit of area per entry. This limit is intended to represent the acreage which, in the opinion of the Secretary, may be reasonably required for the support of a family upon the lands in question. It has been decided that this limit shall be in multiples of 40, excepting in the case of irregular lots shown in the public land surveys. The Secretary, in short, must, after considering the character of the land, designate certain farm units, these being of 40 acres, 80 acres, 120 acres, or 160 acres in extent. The separation of any particular tract of land into farm units is a matter requiring a full knowledge of the soil, its capability of producing crops, and its liability to injury by becoming swampy or alkaline. As is well known, much of the land under an irrigation system tends to deteriorate in character and become incapable of supporting a family unless great care is used in providing drainage or in applying water to the lands in the vicinity.

One of the most important provisions of the law is contained in this section, namely, that requiring these payments of the estimated cost of construction. This is an effective safeguard against undertaking visionary or unprofitable operations, and puts the operations under the law on a sound basis. The fact that each project must return its cost cuts out of consideration at once a large number of the dubious or chimerical schemes that are continually being exploited and removes the temptation to try expensive experiments.

Section 5 defines how payment shall be made and introduces the matter of reclamation of lands in private ownership. At the time the law was under consideration it was supposed that it would be applicable mainly to public lands, but results of surveys and examinations of definite projects are beginning to show that the amount of public land which may be reclaimed is not so large as was anticipated and that the lands in private ownership are frequently more important or more valuable than the public lands. The great and important safeguard in this connection is the restriction of ownership of water for these lands to 160 acres. By carefully guarding this provision and insisting upon compliance with the letter and spirit of the law it will be possible to bring about the subdivision of private lands into relatively small holdings and the intensive cultivation of the soil.

OPERATION AND MAINTENANCE OF WORKS.

Section 6 gives authority for operating and maintaining the works and provides for passing the management to the owners of the land when the major portion of the payments have been made. In short, after the works are in successful operation and have been partly paid for the management passes into the hands of the water users. It has been found essential to consider very carefully the organization of the water users, particularly where a considerable part of the lands are already in private ownership, and there will be found on later pages a more complete discussion of the many problems encountered.

CONDEMNATION PROCEEDINGS.

Section 7 gives the Secretary of the Interior authority to purchase necessary property or to obtain it by condemnation proceedings. Every reasonable effort is being made to avoid condemnation proceedings and to acquire needed properties by mutual agreement.

STATE LAWS.

Section 8 bears upon State laws and vested rights. It brings about the need of a more or less complete study of existing systems of water appropriation and necessitates taking up with State officials and legislators many details of State laws or proposed amendments. It is very important to secure as nearly a uniform system of laws in the various States as may be consistent with the different physical conditions, and it is believed that as time goes on the State laws will be brought into greater harmony with one another and with the necessities of irrigation development.

DISTRIBUTION OF EXPENDITURE.

Section 9 provides that the funds arising in each State and Territory shall be divided into two portions, a major and minor portion, and that the major portion shall be expended in the State in which it arises. For convenience it has been assumed that the major portion is 51 per cent of the fund. This may be termed the restricted portion, since its expenditure is restricted to the State under consideration.

The following table shows the condition of the restricted and unrestricted portions for the various States and Territories on the assumed basis of 51 per cent restricted and 49 per cent unrestricted:

Division of reclamation fund.

State or Territory.	Aggregate.	Restricted portion, or 51 per cent.
Arizona	$193,399.73	$98,633.86
California	1,824,569.32	930,530.35
Colorado	1,651,187.75	842,105.75
Idaho	1,651,477.78	842,253.67
Kansas	109,450.78	55,819.90
Montana	1,797,157.70	916,550.43
Nebraska	492,713.47	251,283.87
Nevada	53,761.42	27,418.32
New Mexico	388,105.73	197,933.92
North Dakota	3,632,799.46	1,852,727.73
Oklahoma	2,637,073.59	1,344,907.53
Oregon	4,158,582.95	2,120,877.31
South Dakota	805,483.79	410,796.73
Utah	284,413.58	145,050.93
Washington	2,599,659.65	1,325,826.42
Wyoming	990,755.93	505,285.52
Total	23,270,592.63	11,868,002.24

RULES AND REGULATIONS.

Section 10 gives general authority to the Secretary to perform necessary acts and make essential regulations, the regulations being promulgated from time to time, as occasion requires, in order that they may be adapted to conditions found in actual practice. The law leaves executive discretion a wide range, and it has not been considered desirable to attempt to anticipate the conditions which might arise, but rather to meet them as they come and to promulgate rules and regulations on the basis of experience.

DECISIONS OF THE SECRETARY OF THE INTERIOR.

The following is a brief statement of decisions of general interest relating to the reclamation act which have been made by the Secretary of the Interior:

WITHDRAWAL OF LANDS.

February 11, 1903.—Two different forms of withdrawal are authorized by section 3 of the reclamation act. The first form provides for withdrawal from public entry of lands required for irrigation works, under which no entries of any kind can be allowed. The second form of withdrawal leaves the land open to homestead entry under the provisions, limitations, charges, terms, and conditions of the act, and is intended to apply to lands irrigable from the works constructed.

September 5, 1903.—There is no authority to make such executive withdrawal of public lands in a State as will reserve the waters of a stream flowing over the same from appropriation under the laws of the State or will in any manner interfere with its laws relating to the control, appropriation, use, or distribution of water.

January 13, 1904.—Withdrawals under the reclamation act operate to withdraw from other disposition all lands within the designated limits to which a right has not vested.

June 28, 1904.—Withdrawal under the second form precludes any other form or mode of entry or appropriation of the land than homestead. Land so withdrawn can not be taken up in lieu of land relinquished to the United States in a forest reserve.

July 12, 1904.—The first form of withdrawal, under which no entries of any kind can be allowed, may be used in all preliminary withdrawals.

RESTORATION OF LANDS.

September 14, 1904.—In an opinion by the assistant attorney-general, approved by the Secretary of the Interior, it is held that when an order of withdrawal is revoked the time for making entries may be fixed at some date in the future, leaving the lands subject to settlement from the date of the order of revocation. This permits a right to attach to such lands, as the result of settlement, in advance of the possible filing of an entry for the same land by one who has not settled thereon.

ENTRIES.

November 17, 1902.—There is no authority for specifying any limitation in the area of homestead entries under the reclamation act in advance of a definite determination to enter upon the necessary construction for the project in question and the issuance of the public notice provided for in section 4. This matter was further considered and a similar decision reached by the Secretary on February 11, 1903.

August 21, 1903.—The Reclamation Service is authorized to classify and combine the different subdivisions within lands withdrawn for irrigation under the reclamation act so as to make practically homestead segregations of the entire territory under one project, specifying the particular legal subdivisions that shall constitute each entry as to all public land included in the withdrawal.

July 6, 1903.—Whenever final proof is offered on any desert-land entry for lands within the limits of the withdrawals for the Reclamation Service, an inspection will be made by the engineers of the Reclamation Service to determine whether the entryman has complied with the desert-land laws and regulations.

January 13, 1904.—A withdrawal under the reclamation act becomes operative upon the lands covered by timber and stone applications when no payment has been made and terminates the contingent right of the applicant.

In cases where valid locations of mining claims were made prior to the date of withdrawal, and the mining laws duly complied with in good faith by the locators or their grantees, the possessory rights so obtained by such locations and duly maintained will be respected by the Government. The requisites of a valid location are (1) discovery, (2) the marking of the location on the ground so that its boundaries may be readily traced, and (3) compliance with local regulations.

January 14, 1904.—By a successful contest against a desert-land entry the contestant does not acquire such a preference right of entry as will, prior to its exercise, except the land from the operation of a withdrawal for irrigation purposes made under the provisions of the act of June 17, 1902.

February 17, 1904.—In a decision of this date certain rules are laid down with regard to the acceptance of final proof in desert-land entries made within the areas withdrawn under the reclamation act, and by circular letter of February 23, 1904, an extract of this decision was communicated to the engineers in charge of projects for their guidance in reporting upon such entries. The extract reads as follows:

> Proof which shows that because of irrigation there is on the land "a marked increase in the growth of grass" or that "grass sufficient to support stock has been produced on all the land" will not be accepted as showing a compliance with that provision of the amendatory act of 1891 (26 Stat., 1095) "that proof be further required of the cultivation of one-eighth of the land." Actual tillage must, as a rule, be shown. If, however, it be shown—and it must be made to conclusively so appear—that because of climatic conditions crops other than grass can not be successfully produced, or that actual tillage of the soil will destroy or injure its productive qualities, the actual production of a crop of hay of merchantable value, as a result of actual irrigation, may be accepted as sufficient compliance with the requirement as to cultivation.
>
> That the entryman has an absolute right to sufficient water to successfully irrigate the land, that the system of ditches to conduct the water to and distribute it over the land is adequate for those purposes, and that the land has been actually irrigated for a sufficient period of time to demonstrate the sufficiency of the water supply and the effectiveness of the system are essential facts which must in all cases be clearly established by the proofs.

April 14, 1904.—Lands withdrawn from "settlement, entry, or other form of disposal under the public-land laws, except the homestead laws," in accordance with the provisions of the act of June 17, 1902, are not, during the continuance of such withdrawal, subject to disposal under the coal-land laws, where no rights thereto were initiated under such laws prior to the order of withdrawal.

March 30, 1904.—Lands withdrawn from entry under the second form of withdrawal (p. 33) are not subject to desert-land entry, even when the applicant has commenced a system of irrigation.

May 17, 1904.—Persons making homestead entry of lands within the irrigable area of any project commenced or contemplated under the provisions of the act of June 17, 1902, will be required to comply fully with the requirements of the homestead law as to residence, cultivation, and improvement; and failure to supply water from such works in time for use upon the land entered will not justify a failure to comply with the law and to make proof thereof within the time required by the statute.

WATER RIGHTS.

March 20, 1903.—The Director of the Geological Survey is authorized to designate suitable persons to file notices of water appropriation for the projects of the reclamation service, in the name of and on behalf of the Secretary of the Interior, in pursuance of the provisions of section 8 of the reclamation act.

September 5, 1903.—There is no authority to make such Executive withdrawal of public lands in a State as will reserve the waters of a stream flowing over the same from appropriation under the laws of the State or will in any manner interfere with its laws relating to the control, appropriation, use, or distribution of the water.

RIGHTS OF WAY.

May 6, 1904.—No rights are acquired by an application for a right of way under the act of February 15, 1901, prior to the approval thereof by the Secretary of the Interior.

No such right is acquired by virtue of an application for right of way for a railroad under the act of March 3, 1875, before the approval thereof and prior to the construction of the road, as will prevent the Secretary from withdrawing the lands covered thereby for use as a reservoir site under the provisions of the act of June 17, 1902.

June 4, 1903.—The act of August 30, 1890, with regard to reservations for rights of way, does not apply to (1) land taken under the indemnity clause of railroad land grants which has actually been selected; nor (2) to various school land grants to States or Territories; nor (3) to indemnity school selections; nor (4) to educational and other grants to States and Territories, where selections have been made; nor (5) to special grants by acts of Congress.

June 17, 1904.—Where a right of way for a reservoir site has been granted under the act of March 3, 1891, which provides that entries subsequent to such grant shall be subject thereto, the United States, in purchasing the rights of such grantee, does not succeed to the superior rights granted by said act as to entries made subsequent to such grant; and the right to flood and appropriate lands and improvements under such subsequent entries must be acquired by the United States by agreement or by condemnation proceedings.

RIGHT-OF-WAY APPLICATIONS.

July 14, 1902.—The Commissioner of the General Land Office was instructed to submit to the Director of the Geological Survey, for his consideration and report, all applications for rights of way over the lands withdrawn for the uses of the reclamation service.

September 18, 1902.—The above instructions were extended to cover rights of way applied for within the limits of forest reserves.

June 23, 1903.—The Commissioner of the General Land Office was instructed to submit to the Director of the Geological Survey all the applications received for rights of way for canals or reservoirs in any of the States or Territories subject to the operations of the reclamation act.

SURVEYS.

May 9, 1903.—As the land which it is proposed to reclaim under some of the projects now being studied has not been subdivided in accordance with the public-land surveys, and as such subdivisions will be necessary in order to make proper descriptions for the disposal of the same, the Secretary decided that the necessary public-land surveys could be ordered whenever they were found advisable.

July 14, 1903.—The Director is authorized to instruct the engineers and topographers of the Reclamation Service to retrace and re-mark the public-land lines within the areas under survey with a view to their reclamation.

ARTESIAN WELLS.

March 3, 1903.—The reclamation fund can not be used for drilling artesian wells for exploration. Such wells may be paid for from the reclamation fund only in cases when there is sufficient knowledge in advance to make it probable that water will be obtained from them in sufficient quantities for the irrigation of lands, with the probability that the cost will be returned to the reclamation fund.

LAND PURCHASES.

March 20, 1903.—Whenever the Director is authorized by the Department to enter on negotiations looking to the acquisition by the United States of rights or property, or both, he will designate such persons as he thinks proper to carry on such negotiations.

April 28, 1903.—The expenses of procuring abstracts of title to lands or rights is payable from the reclamation fund, provided the land or rights are to be purchased and not condemned.

December 30, 1903.—The Secretary authorized the examination and approval of land titles by district attorneys and instructed them to report thereon to the assistant attorney-general for the Department of the Interior for final examination and action.

January 28, 1904.—When land the acquisition of which is necessary is not needed at once and can be purchased for a less price if the vendor is allowed to retain possession until the land is needed, an arrangement to that effect may be entered into. But after purchase and possession by the United States such lands can not be leased.

April 8, 1904.—Where the purchase of real property is contemplated the title thereto will be passed upon by the assistant attorney-general for the Department of the Interior.

LANDS IN PRIVATE OWNERSHIP.

May 21, 1904.—Where lands are in private ownership in blocks of more than 160 acres the excess may be conveyed to members of the owner's family, provided the transfer is bona fide and the requirements of the reclamation act as to residence are complied with.

August 30, 1904.—In regard to the disposition under reclamation projects of lands in private ownership held in tracts of more than 160 acres by any one person, it was held that the views of the Department as to the necessities of the case would be satisfied by any agreement drawn upon the lines suggested in the forms adopted by the Uncompahgre Valley Water Users' Association or the Yuma County Water Users' Association. These forms provide for vesting in these associations the title to the excess of lands owned in blocks of more than 160 acres and authorize them to sell the lands in case of the failure of the owner to dispose of them to persons qualified to apply for water rights under the reclamation act by the time the Government is ready to furnish the water.

OPTIONS.

April 28, 1903.—Payment of a sum of money for an option for a right of way, water right, or land needed for the reclamation work would not be a proper expenditure from the reclamation fund.

EXCHANGE OF LANDS.

February 20, 1904.—The Secretary has no authority to permit the owner of lands that are needed for a reservoir to be constructed under the terms of the reclamation act to select other lands of the same area within the district that may be made susceptible of irrigation from the proposed reservoir in exchange for the lands so needed for reservoir purposes.

PRINTING.

October 28, 1903.—In view of the opinion of the Assistant Comptroller dated October 21, 1903, that the Secretary of the Interior is authorized, under the provisions of section 10 of the reclamation act, to prescribe, by rule and regulation, the manner in which printing may be done by engineers in the field, the Secretary authorized the Director to have the requisite printing done locally, when necessary in the prosecution of reclamation work, and directed that it be paid for from the reclamation fund.

SALOONS.

February 25, 1904.—Withdrawals under the first form of withdrawal (p. 33) are absolute, and the Department may remove persons from such lands as trespassers. But the keeping of a saloon by a homesteader upon his claim is not sufficient to invalidate his settlement or entry if he continues to comply with the homestead law.

INDIAN RESERVATIONS.

February 9, 1904.—As a rule, ceded Indian lands are subject to disposition under certain specific acts mentioned in the treaty or the act of Congress providing for the cession, and hence would not be subject to withdrawal under the provisions of the reclamation act. Specific decisions will be made on each case.

ORGANIZATION OF THE RECLAMATION SERVICE.

HISTORY OF SERVICE.

The origin of the Reclamation Service has been described in general terms in the annual reports of the Secretary of the Interior. It has been shown that this work is the outgrowth of the explorations of Maj. J. W. Powell throughout the arid West, reported to Congress in his book entitled "Lands of the Arid Region." For more than a decade after this report was published Major Powell continued the agitation for governmental action, and in 1888 he, as Director of the Geological Survey, was authorized to investigate the extent to which the arid region might be reclaimed by irrigation. He pushed forward energetically the work of mapping the mountainous catchment basins of the streams and locating the irrigable land.

In 1894 a specific appropriation for gaging streams was made by Congress, and work in this direction was extended from time to time until a large amount of general information was available concerning the arid West and the opportunities for development under irrigation. When the reclamation law went into effect on June 17, 1902, there existed a small corps of engineers comprising what was known as the division of hydrography of the Geological Survey. These men, trained through years of practical experience, became the nucleus of the Reclamation Service, which was organized for administrative purposes as part of the Geological Survey.

In a great work of this kind, under a new and untried law, the advantage of such form of organization is very great. The Reclamation Service, by adopting the useful precedents set by the older organization, was able to start at once upon its large work and to push forward rapidly in the larger fields. It started with comparatively few men, and others have been added through the operations of the civil-service law, competitive examinations being held for various classes of work. Although it has been but a little over two years since the Reclamation Service was organized, its operations have been pushed forward so energetically and widely that it has made surveys and examinations and begun construction work throughout nearly one-half of the United States.

CLASSIFICATION OF ENGINEERS.

The members of the Reclamation Service are divided into various grades, so grouped as to distribute responsibility and yet to place it clearly upon each individual. The younger men taken into the service are designated as "engineering aids." They are selected in competitive civil-service examinations and are given the customary six months' probation. If at the end of that time they are found to be men of intelligence, ability, and good character, they receive indefinite appointments. At short intervals the record of each of these young men is scrutinized, reports of their superior officers are examined, and recommendations are made by a board on personnel as to advancement to a higher grade and larger duties. They usually receive at first from $60 to $75 per month, according to experience or education, and after two or three years may be advanced step by step until they are designated assistant engineers.

The assistant engineers are young men of moderate experience and are graded at salaries of from $1,200 to $1,600, advancement being made by careful consideration of the ability displayed, both in engineering operations and in matters regarding business ability and tact. An assistant engineer in charge of a field party has under him engineering aids and men temporarily employed, such as teamsters, packers, cooks, etc.

Next in order are the engineers, who are men approaching middle age and who have had practical experience in irrigation work or construction. The engineers receive from $1,800 a year upward. Each is in charge of one or more parties in surveys or construction.

The district engineers are men of higher grade, each of whom has been assigned to work in a particular drainage basin or portion of a State. In a large measure they take the initiative and direct the work. They have, as a rule, been engaged for many years in development work or construction, and have a wide general knowledge and special experience. Each district engineer has control of the engineers and assistants detailed for work in his particular district.

The district headquarters are as a rule at the largest project in hand or at some point of convenient access to the project. The engineering financial records are kept at the district office, and suitable copies or abstracts are sent to the office of the chief engineer at Washington. A disbursing clerk also is located at the district office and pays all accounts except claims for large amounts submitted by contractors or arising from the purhase of land; these are usually settled through the Treasury Department.

A number of consulting engineers are provided to advise and assist in all of the technical branches of the work. Each consulting engineer gives his attention to some particular group of districts or class of problems. These men are not burdened with administrative details, but give their time exclusively to engineering matters.

A number of supervising engineers, representing the chief engineer in the field, look after the larger administrative problems where prompt action is required and inspect, and direct, or give advice concerning the important work.

The chief engineer and assistant chief engineer have full charge of all engineering and administrative matters, dividing their time between the Washington office and the field, the chief engineer giving particular attention to departmental and related matters and the assistant chief engineer spending the major part of his time in the arid regions, visiting the works and serving as supervising engineer. A considerable portion of his time is also spent in the Washington office, relieving the chief engineer while in the field and permitting administrative matters to proceed without interruption.

ENGINEERING BOARDS.

The supervising, consulting, and other higher classes of engineers are organized into committees or boards for the purpose of considering various problems. Each board is organized so that its members consist of men who are thoroughly familiar with the matter in hand. Each person also serves on other boards, so that he is brought in contact with similar conditions elsewhere. The boards consist usually of three or five members, and may invite the assistance or advice of citizens and business men interested in the project in hand.

Whenever a district engineer has brought his plans and estimates to a point where they can be discussed as a whole they are transmitted to the chief engineer and by him referred to a project board convened upon a specific date for the purpose of considering them. The board as a rule consists of the supervising engineer for the division, one or more consulting engineers, and the district engineer. Each has been over the ground from time to time, and has broad information upon the whole subject, from the foundations upward.

The project board may be in session for several days, or until a definite report to the chief engineer can be prepared. It recommends the approval or modification of the plans or calls for further information on certain particulars.

The action taken by the board, if conclusive, is then considered by the chief engineer, and recommendations are made through the Director of the Geological Survey to the Secretary of the Interior, and upon these recommendations the Secretary takes action.

PERSONNEL.

The reclamation law is very general in its provisions and leaves to administrative discretion a vast number of important and far-reaching matters. Extraordinary care has been used in the selection of the men who are to put the act into effect and upon whose individual judgment and integrity the success of the law must depend.

The conditions under which the work of the Reclamation Service is carried on are such that elaborate laws or regulations can not well be promulgated; these must be the outcome of experience obtained day by day, rather than the expression of theoretical knowledge. The problems are not those merely of engineering, but involve dealing with a large range of social and political conditions. The requirements of the law are not simply to build great works safely and economically, but, far more than this, to put them into operation so as to bring about the creation of a prosperous community consisting of hundreds or thousands of individuals, and to put the operation and maintenance of these works in the hands of such a community. For this it is necessary to see that all details are worked out so that the community management will permanently give good results.

The difficulties to be overcome are such as to necessitate putting the initiative into the hands of men who have given the subject the best thoughts of a lifetime. The men must be guarded and protected from all external pressure or selfish consideration. In the organic law of the Geological Survey it is stated that the Director and members shall have no personal or private interests in the lands or mineral wealth of the region under survey, and shall execute no surveys or examinations for private parties or corporations. This law is regarded as a guide for the Reclamation Service, which has been placed under the Geological Survey, and although its enforcement may be considered as occasionally working hardship, yet, in the long run, it is believed to be good administrative policy to see that its provisions are carried out.

During the two years since the reclamation law was passed the Reclamation Service has been developed upon broad lines and the most important precedents for future guidance have been set. It may be said to have passed the formative period, and while future growth is anticipated, the dangers of early youth have been passed. Each individual understands thoroughly that his retention in the service and future advancement depend wholly upon ability and merit and that influence in all forms is rigidly barred.

CHARACTER OF OPERATIONS.

EXTENT OF WORK.

The operations of the Reclamation Service, as provided by the act of June 17, 1902, relate to examinations and surveys for irrigation works and the construction of these after their feasibility has been determined. Many of the preliminary surveys have been made in part by the topographic and hydrographic branches of the Geological Survey, maps having been made of some of the catchment basins and observations of river flow continued through a series of years. The general knowledge thus obtained in the past is being utilized in its bearing upon specific problems.

A general examination of the entire arid and semiarid region is being carried on, and the knowledge already obtained is being extended and completed in detail. Whenever an apparently feasible project is called to the attention of the engineers the work is concentrated upon the locality in order to obtain definite facts. The results of the surveys are carefully considered in relation to the cost and probable benefits of the work, and investigations are carried to a point sufficient to settle without question whether under existing circumstances an irrigation project is practicable.

PRELIMINARY WORK.

Every effort is being made to expedite the work of the Reclamation Service, and general instructions are issued to all responsible engineers in the field to carry on the work as rapidly and economically as would be done by individuals or corporations.

It is recognized that there are necessary limitations in governmental work. Efforts are made, however, not only to comply with the spirit of the law, but to execute the work economically and well, and, general authorization having been obtained, to proceed without loss of time. This is a matter of fundamental importance in conducting work in remote localities, since precise insistence upon minute regulations would inevitably lead to the tying up of operations and to the wasting of large sums of money while definite orders are awaited or problems of official routine are solved.

In order to permit the responsible men to transact business rapidly and economically it is necessary to give them general instructions and to hold them to the prompt and effective accomplishment of results, the work not to be delayed by the necessity of applying to Washington for every step in the proceedings. At the same time it is insisted that care be taken to avoid entanglements growing out of the short cuts, which, while feasible for individuals, are prohibited by laws or departmental regulations.

There is naturally much impatience expressed at the slowness with which the reclamation fund is being expended. It is believed, however, that the work is being pushed as rapidly as possible consistent with thoroughness and economy. The works to be built by the Government should be permanent in character and designed with reference to complete development. These works are in striking contrast with those built by private enterprise, since the latter are largely temporary in character and are often built with the minimum amount of capital, their projectors having in mind gradual renewal and increase as funds may be had. Headworks, flumes, and other structures are thus usually built of wood, the ditches are dug so that they may be enlarged, and as the country develops and the old structures decay new headworks and flumes are built with reference to the increasing needs.

The Government works, however, are designed to cover all of the land which can be developed, and each structure must be as nearly permanent as stone, concrete, or steel can make it. The size and shape of these structures can not be modified from time to time, and hence in the original design they must furnish all needs. At the same time money must not be wasted by building them of excessive size or by giving them a strength not demanded by probable conditions.

Each structure must therefore be thought out with reference to the future, and the drawings and computations made with a far greater degree of thoroughness than is needful in private work. There are no standard sizes or conditions, such as prevail in many other branches of engineering. In designing a railroad or waterworks system, for example, there are certain standard sizes and forms of material to be used, and the prices are well established. It is a matter largely of putting together parts, the cost of which is well known. In irrigation construction on a large scale, however, there are no standards or conditions, and each large system must be developed from original plans.

The engineering side, however, does not offer usually as great causes of delay as the legal or human element. There are almost everywhere land titles to be adjusted, rights of way to be secured, and claims to water to be considered. The claims to water are frequently of the most elusive character, and great patience and occasionally judicial decisions are required to determine their extent.

Great numbers of persons must be dealt with individually and collectively in planning most of the irrigation projects, and they must be systematically educated along the lines that must be followed. Popular impressions concerning the reclamation law and its effects are frequently erroneous, and in many cases the people do not have a correct knowledge of their opportunities and duties. All the false impressions must be removed and steps taken to induce the people to enter into contracts regarding the future use of water. Experience has shown that such agreements or contracts can be more readily made before construction is begun than later.

It is frequently necessary to delay work in order to secure the proper execution of agreements relating to lands or rights to be acquired. In every instance organizations and individuals promise in vague terms to cooperate or assist; when, however, a definite agreement is to be made there is frequent hesitation, and the only way to bring matters to a conclusion is to state plainly that the work of construction will not begin until the necessary agreements have been made.

CONTRACT WORK.

In section 2 of the reclamation act the Secretary of the Interior is authorized to construct the irrigation works, and by section 4 he is authorized, upon the determination that any irrigation project is practicable, to let contracts for its construction in portions or sections. The portion of the act which relates to letting contracts, taken in connection with the law as a whole, is plainly permissive rather than mandatory. Most of the construction work can best be done by contract, but some of it can only be effectively undertaken by employing labor on what is known as "force account."

The contracts for construction are prepared according to the usual procedure of corporation or departmental undertakings. After the plans and specifications prepared by the district engineers have been submitted to the project board and approved by the Department they are made public, advertisements are inserted in publications reaching the largest number of probable competitors, bids are received, and contracts are awarded to the lowest bidders. Most of the procedure is defined by law and by precedents that have been established through long usage.

PROPOSALS.

Instructions have been issued from time to time with regard to the opening of bids and the making of abstracts thereof and reports thereon, which may be summarized as follows:

The report of the board designated to open the bids begins by stating that the bids were opened at the time and place mentioned in the advertisement, and that all the bids received are transmitted therewith. It contains a specific recommendation as to the award of the contract, and an alternative recommendation in case the party to whom the award is made fails, for any reason, to execute the contract. If recommendation is made that the contract be awarded to any other than the lowest bidder, the reason for such recommendation is stated.

An abstract is made of all the proposals received, containing the names of the bidders and the prices bid, the entries on the abstract being made in the order of the amounts of the bids—the lowest first, then the second lowest, and so on. Two copies of the abstract are sent to the chief engineer with the report of the board, and copies are sent to technical papers which make a practice of publishing such matter.

Water-Supply and Irrigation Paper No. 93 contains general information concerning this subject, including the regulations of the Indian Office applicable thereto.

FORCE-ACCOUNT WORK.

Work under the co-called " force account " is performed on minor construction where it is impracticable to give in advance an accurate description or estimate of the conditions to be encountered—in such work, for example, as digging test pits, making borings by diamond drill, carrying on exploratory work, or making examinations of unknown ground. There is also in connection with every large contract much miscellaneous work which connects up the various sections, more or less finishing to be done, and details to be executed without delay. These can be accomplished most effectively by employing men and machinery at the exact instant when the conditions are favorable—as, for example, at times of extraordinary flood or unusual drought.

Force-account work also includes various operations that can not be successfully let by contract and those where the conditions are so involved or unusual that competition is not practicable. For instance, in some parts of the arid region where reservoirs must be built the field of work is so remote from centers of population or lines of transportation that, in the preliminary stages at least, competition is impossible and contractors must bid high to cover unknown conditions. Here the contract system is not consistent with economy and good administration, and it is necessary to carry the work by day-labor to a point where contractors can successfully bid.

In order to execute force-account work a considerable equipment of machinery and tools is necessary; in short, the Reclamation Service, like any large corporation doing such work, must have a considerable plant of its own and be able to execute work under unusual conditions.

Most of the engineers of the Reclamation Service have been in private practice and have had responsible charge of large undertakings, and experience shows that work is carried on more economically under this "force account" than under the contract system. Contracts, however, are entered into whenever practicable, particularly when the work to be done is such that competition can be secured and contractors will do the work with a reasonable assurance of a fair margin of profit.

FIELD HEADQUARTERS.

During the period of reconnaissance and preliminary survey offices for the various district engineers and their assistants are, as a rule, rented in suitable office buildings in conveniently located cities or towns. As soon as active construction begins it is necessary to transfer the principal offices to the locality of work in the field, in order that the draftsmen, inspectors, assistant engineers, and others connected with the work may be at all times in close contact with it. This necessitates the construction of field headquarters and accommodations for a considerable number of men. For this purpose temporary or movable buildings are erected or a permanent building is constructed to be used in the future by the gate keeper or water master in control of the operations of the reservoir or large work.

In the extreme south, notably in Arizona, when large works are being constructed, precautions must be taken to insure the health of the men engaged in supervising or inspecting the work. For this purpose hospital facilities are provided, an ice-making plant is installed, proper sanitary arrangements are made, and all other necessary details looked after.

The following table gives the location of the offices rented for the Reclamation Service:

Offices rented for Reclamation Service.

Locality.	Lessor.	Engineer.	Name of building.	Number of rooms.	Cost per month.
Phoenix, Ariz	Central Avenue Improvement Co.	Louis C. Hill		7	$65.00
Los Angeles, Cal	F. W. Pickard	J. B. Lippincott	Braley	5	100.00
San Francisco, Cal	H. E. Law	do	Rialto	1	46.00
Denver, Colo	Chamber of Commerce and Board of Trade.	A. L. Fellows	Chamber of Commerce.	11	150.00
Montrose, Colo	Deeble & Gibson	do		4	40.00
Boise, Idaho	Peter Sonna	D. W. Ross	Sonna	5	65.00
Glasgow, Mont	H. Cosner	C. C. Babb		4	20.00
Malta, Mont		do		4	20.00
Reno, Nev	C. E. Clough	L. H. Taylor		4	47.00
Wadsworth, Nev	R. H. Cowles	do			10.00
Roswell, N. Mex	L. K. McGaffey	W. M. Reed		4	27.50
El Paso, Tex	M. Miller & Co	B. M. Hall	Trust	2	80.00
Pendleton, Oreg	C. C. Hendricks	J. T. Whistler			15.00
Belle Fourche, S. Dak	M. W. Reed	R. F. Walter	Mullenger	4	20.00
Salt Lake, Utah	J. E. Dooley	G. L. Swendsen	Commercial Club	8	106.50
Spokane, Wash	Jno. H. Peet	T. A. Noble	Peyton Block	3	25.00

RELATIONS TO PRIVATE ENTERPRISE.

IRRIGATION DEVELOPMENT.

Among the most difficult matters to be considered is the relation between private enterprise and the operations of the Reclamation Service. It must be borne in mind at all times that practically all of the irrigation development of the West has been carried on by individuals or associations, and that while most of the easily constructed works have built there are others which are still attractive to the promoter. In nearly every locality where there are opportunities of reclaiming public lands on a large scale it also happens that there is something which may be made a source of profit to a shrewd investor.

It may be said, generally speaking, that no large development work has been financially successful. It has frequently been pointed out that all irrigation works may be divided into two classes, roughly designated as large and small. The small works or ditches built by farmers or associations of settlers have, almost without exception, been successful in every respect. The large enterprises, where stock and bonds have been sold and capital has been brought in from the East or from foreign countries, have, almost without exception, proved financially unprofitable and have had a long and involved history of disappointment and occasional bankruptcy. Nevertheless, in spite of this almost universal experience, there are still optimists who plan to avoid all failures of the past, and prepare glowing prospectuses of new enterprises which, if properly manipulated, will bring large returns to investors. As soon as the Government shows an interest in any particular locality some energetic promoter at once concludes that there may be something there which may be of value to himself. If it should be decided that a project must be stopped as soon as any private interest of this kind is encountered, the work of the Reclamation Service would soon come to a halt.

Nearly every possibility of reclamation has been under consideration by somebody at some time, and while every effort should be made to avoid interference it is not fair to the communities concerned nor to the Commonwealth for the Reclamation Service to step aside in favor of speculative enterprises, especially when they would only partly develop the opportunities.

The following paragraphs are quoted from an unpublished statement by Senator Thomas R. Bard:

> It is recognized that the primary purpose of the reclamation act is to utilize the public domain by means of irrigation and make it available for occupation by settlers. The right to the use of the water provided by the expenditure of the reclamation fund must be permanently attached to the land irrigated, and "beneficial use" is made the basis, the measure, and the limit of the right. In every case where a considerable part of the irrigable lands are owned by the Government it is clearly inconsistent with the spirit of the act to permit such lands to be subject forever to a load of charges for interest and profits to be paid upon private capital invested in the irrigation works, these charges being in addition to a high cost of maintenance. This is especially questionable where the water, instead of being attached to the land as an appurtenant right, is owned and controlled by nonresident landlords.
>
> The reclamation act applies also to land in private ownership, and it is plain that the general welfare of the nation requires that the water resources should be made to subserve the greatest possible good. The declaration of the law that the right to the use of the water shall be appurtenant to the land and that beneficial use shall limit the right must be understood as a recognition of the general principles and policies.
>
> By keeping the obvious intent of the law in mind it will be possible to solve many of the difficult questions which arise when private irrigation enterprises interfere with Government projects. It is clearly the duty of the Reclamation Service to investigate and determine whether a given private enterprise is competent to utilize the irrigation resources to the fullest extent and whether the private works are of a permanent character. It is entirely proper for the

Service to refuse to abandon its own projects until satisfactory guaranties are given that these requirements will be provided.

In short, the Service may, in the interest of the public, determine what shall be the character and scope of the work to be undertaken by private enterprise in this particular locality and what shall be the burden to be carried by the irrigated lands, and may properly assert that a compliance with such requirements shall be the condition upon which the Government shall surrender its right to provide the works and abandon its project.

The reservoir sites and similar essential portions of a comprehensive project should be withdrawn from speculative entry by the Reclamation Service and held for the largest practicable irrigation development. In cases where withdrawals have been made and investigations begun, and where promoters ask the Reclamation Service to step aside for their own benefit, they should be able to show, first, that they intend to construct in good faith and are not merely speculators, and, second, that the project to be constructed will be of real public benefit, will develop the country fully, and will not act as an obstruction to more comprehensive or economical systems.

SPECULATION IN WATER POWER.

One of the difficulties encountered in putting the reclamation law into effect is the fact that speculative interests have filed upon, or are seeking to file upon, all possible sites for developing power. Competent men systematically travel through the country hunting up suitable localities which can be filed upon under existing laws and held either for speculative purposes or to prevent development by competitors. If, for example, an individual or corporation can secure all of the available power sites within a certain area, he is able to establish a monopoly and dictate his own terms as regards the future development of many industries. The fact that the persons who file upon these water powers are not compelled to utilize them or expend any considerable amount of money in their development enables a monopoly of this kind to be created at small expense.

PROJECTS IN HAND.

The work in hand may be considered under several groups: (1) Projects—one in each State and Territory—which are proposed for early construction; (2) projects which are being seriously considered as alternatives to be taken up at the first opportunity, and (3) general reconnaissance surveys to ascertain the relative merits of various schemes and to acquire facts upon which to base careful reports. The location of the principal project is shown on Pl. I.

PRINCIPAL PROJECTS.

The list on page 50 gives the principal projects in each State which, from present knowledge, appear to be most desirable for pushing to completion. Some of these have been definitely approved by the Secretary of the Interior and others are in various stages preliminary to such approval. The steps leading up to the adoption of a project are about as follows:

First, a reconnaissance is made which determines in a general way the desirability of making a definite survey. When this survey is well advanced or has been completed the project is brought to the attention of the Secretary for tentative approval, and authority is obtained for further detailed investigation and for the acquisition of lands or rights which may be needed. The next step is generally the completion of detailed drawings and specifications. The whole matter is then referred by the chief engineer to a project board for careful consideration and report.

Principal projects under consideration.

State.	Project.	Acres irrigable.
Arizona	Salt River	160,000
California	Yuma	130,000
Colorado	Gunnison	125,000
Idaho	Minidoka	130,000
Montana	Milk River	60,000
Nebraska	North Platte	100,000
Nevada	Truckee	150,000
New Mexico	Hondo	10,000
North Dakota	Fort Buford	66,000
Oregon	Malheur	90,000
South Dakota	Belle Fourche	85,000
Utah	Utah Lake	60,000
Washington	Palouse River	100,000
Wyoming	Shoshone	175,000

The estimated cost per acre of this reclamation ranges from $20 to $30 and averages about $25.

In addition to the principal projects above listed reconnaissance surveys are being carried on in each of the 13 States and 3 Territories, and alternative projects are also being examined with a view to construction if the principal projects are for any reason found to be impracticable. It is proposed to have these alternative projects carefully examined and ready for construction as soon as the principal projects are out of the way. The following paragraphs give briefly the present stage of knowledge concerning each of the principal projects:

Arizona.—The Salt River project contemplates the storage of water for irrigating approximately 160,000 acres of land and the developing of pumping facilities for an additional acreage. The cost will probably be about $20 per acre, and ultimately from $3,000,000 to $4,000,000 will be expended.

California.—The Yuma project, on the lower Colorado River, as now outlined involves the reclamation of about 130,000 acres at a cost of $40 per acre, the land being on both sides of the river, in California and Arizona.

Colorado.—The Gunnison project contemplates the reclamation of 125,000 acres of lond in the Uncompahgre Valley, at a cost of about $30 per acre. This land is largely in private ownership. The project involves the building of a tunnel 6 miles long from Gunnison River.

Idaho.—The Minidoka project is designed to reclaim about 130,000 acres of vacant public land on both sides of Snake River, at a cost of between $25 and $35 per acre. This is to be accomplished by the construction of gravity and pumping systems.

Montana.—The Milk River project is designed to reclaim nearly 60,000 acres of land, mostly public, located mainly on the south side of Milk River, east of Malta, Mont. Water will be stored in reservoirs. The cost will be from $20 to $25 per acre.

Nebraska.—The North Platte project is designed to reclaim an undetermined area on both sides of North Platte River, in both Wyoming and Nebraska. Water will be stored in Wyoming and canals built, heading in that State. Most of the land is now in private ownership. The cost of reclamation will probably be about $35 per acre.

Nevada.—The Truckee project, now under construction, will reclaim upward of 150,000 acres, at a cost of about $26 per acre. There are a number of ramifications which are yet to be worked out, and these may result in a larger development.

New Mexico.—The Hondo project, in the vicinity of Roswell, will irrigate about 10,000 acres, a portion of which is in private ownership. The cost will be upward of $28 per acre. Water is to be obtained from flood storage in a reservoir to be constructed on the north side of Hondo River.

North Dakota.—The Fort Buford project is designed to reclaim 66,000 acres on the west side of Yellowstone River, in Montana and North Dakota, at a cost of about $31 per acre. Most of this land is in private ownership.

Oregon.—The Malheur project, on both sides of Malheur River, west of Ontario, will reclaim, by storage of flood waters of Malheur River, about 90,000 acres at a cost of about $30 per acre.

South Dakota.—The Belle Fourche project contemplates the reclamation of 85,000 acres of arid land, largely public, situated north of the Black Hills, by the storage of flood waters of Belle Fourche River. The cost will be about $32 per acre.

Utah.—The Utah Lake project contemplates the utilization of waters tributary to Utah Lake and the reduction of evaporation losses by drawing down the lake. It is possible that 60,000 acres may be reclaimed, at a cost of $35 per acre.

Washington.—The Palouse project is for the redemption of arid lands near Pasco by storage in Washtucna reservoir. Possibly 100,000 acres, mainly in private ownership, can be reclaimed, at a cost of $30 per acre.

Wyoming.—The Shoshone project is designed to reclaim 175,000 acres of public land in the Bighorn basin, north of Shoshone River. Water will be stored and diverted at a cost of $25 per acre.

SECONDARY PROJECTS.

Besides the primary projects which have been approved by the Secretary for each of the reclamation States, there are under consideration other enterprises which are almost equally important, or which may be brought forward upon the completion or abandonment of the primary projects. Some of these will require many months or years of systematic investigation, but they will presumably be ready for final determination by the time the funds will permit their construction. The following list gives the secondary projects in the various States and Territories:

Arizona.—San Carlos: Water supply being considered. Also pumping plant for Sacaton Indian Reservation.

California.—Owens Valley: Preliminary surveys and stream measurements. Possible increase of irrigated area from 30,000 to 90,000 acres. General study of Sacramento Valley and headwaters of tributary streams, with a view to complete development of the valley. Reservoir surveys being made of five sites on Pit River tributary. Klamath River: General study of water supply, reservoir sites, and irrigable areas.

Colorado.—Grand River project. White River project.

Idaho.—Payette-Boise project: Surveys in progress and people organizing water users' association.

Kansas.—Underflow possibilities being examined along Arkansas and Cimarron rivers.

Montana.—Sun River project: Lands segregated and reconnaissance being made.

Nebraska.—Extension of North Platte project.

Nevada.—Measurements of streams and examination of reservoir sites.

New Mexico.—Engle dam on Rio Grande to use water for lands above and below El Paso. Lands withdrawn for La Plata project. Urton Lake surveys being continued and estimates prepared.

North Dakota.—Preliminary surveys being made on Little Missouri and Mouse River projects. Pumping from Missouri River.

Oklahoma.—Reservoirs being surveyed on request of various officials or communities.

Oregon.—Umatilla project being surveyed; searching for reservoir site.

South Dakota.—Cheyenne River project.

Utah.—Bear Lake project: Preliminary surveys nearly completed; area involved, 100,000 acres.

Washington.—Big Bend and Okanogan projects under survey.

Wyoming.—Lake De Smet project being investigated. Also Wind River Indian Reservation.

RECONNAISSANCE SURVEYS.

In addition to the primary projects already approved and the secondary projects under examination reconnaissance surveys for general knowledge of other opportunities are being conducted throughout the arid region. The principal localities in which reconnaissance surveys are being made are given in the following list:

Arizona.—Examination of tributaries of Gila River and of headwaters of San Pedro River above Benson. Examination of underground waters.

California.—Examination of underground waters in southern part of the State.

Colorado.—General examination of streams in northwestern part of State and search for reservoir sites on Grand River.

Idaho.—Examination of water supply and reservoir facilities for Dubois project and measurement of streams in other parts of the State in connection with possible developments.

Kansas.—Search for sites which may be filled from Arkansas River.

Montana.—Reconnaissance of Crow Indian Reservation, of Bitterroot Valley, and of Madison River project.

Nebraska.—Examination of streams in northwestern corner of State.

Nevada.—Survey of Walker and Humboldt rivers. Seepage and evaporation investigations.

New Mexico.—Examination of the Rio Grande and its possibilities for water storage.

North Dakota.—General search for reservoirs and feasible projects and examination of pumping projects.

Oklahoma.—Search for feasible projects of water storage.

Oregon.—Possible projects developed from Chewaucan and Ana rivers in central Oregon. Examination being made of extreme upper waters of Deschutes River.

South Dakota.—Examination of water supply of Rapid Creek and Owl and Grand rivers and their storage possibilities; also stream measurements on Cheyenne and White rivers.

Utah.—Strawberry Valley and Uinta Indian Reservation.

Washington.—Study of water supply in Yakima Valley and opportunities for reclamation by pumping near Priest Rapids. Investigations in Kootenai basin.

Wyoming.—Reconnaissance of Green River and measurements of streams.

SEGREGATIONS.

The following table gives the number of acres temporarily withdrawn pending surveys and the acreage restored to entry by States to June 15, 1904. This shows that there remain segregated over 40,000,000 acres, out of which probably more than 1,000,000 acres may ultimately be reclaimed.

The amount of land temporarily withdrawn pending survey, while apparently large, is not as great as the figures indicate, because the segregation is made usually by townships, and out of these townships the greater part of the available land has already been entered and is in private ownership. The remaining areas which are affected by this temporary segregation are perhaps valueless and have been passed over on that account, or they may contain valuable tracts which may still be entered under the homestead law.

Areas withdrawn from and restored to entry.

State.	Withdrawn.	Restored.	Remaining withdrawn.
	Acres.	*Acres.*	*Acres.*
Arizona	3,325,000		3,325,000
California	2,666,860		2,666,860
Colorado	1,847,390	388,030	1,459,360
Idaho	3,713,440		3,713,440
Kansas			
Montana	9,576,160	1,035,000	8,541,160
Nebraska	2,631,640	46,000	2,585,640
Nevada	4,632,960	203,560	4,429,400
New Mexico	1,441,940	161,000	1,280,940
North Dakota	1,013,720		1,013,720
Oklahoma			
Oregon	2,721,000	598,000	2,123,000
South Dakota	1,708,450		1,708,450
Utah	92,000		92,000
Washington	4,739,490	69,000	4,670,490
Wyoming	3,363,440	956,210	2,407,230
Total	43,473,490	3,456,800	40,016,690

WATER USERS' ASSOCIATIONS.

Much time and thought has been devoted to the organization of water users' associations or organizations, owing to the fact that in many of the projects in hand it becomes indispensable to deal with large number of landowners and others concerned in the reclamation of particular tracts. If all of the land under any one project were in public ownership, it would not be necessary to organize the people into an association until the time contemplated in section 6 of the reclamation act, viz, when payments have been made for the major portions of the lands irrigated. As a matter of fact, however, many of the projects under consideration embrace tracts of land in private ownership, and it is necessary to deal at the outset with several hundreds or even thousands of landowners. If the project is carried out, these landowners must ultimately be brought together through an organization for the management and operation of the irrigation works. It is found essential to create this organization at an early date, so that instead of dealing with hundreds of individuals separately it will be possible to transact business with one man or with a small committee of men representing all of the water users.

The initial step toward the formation of these water users' associations was taken in Salt River Valley in Arizona, where the people, under the leadership or advice of B. A. Fowler, president of the existing association, Judge Joseph H. Kibbey, and George H. Maxwell, counsel, drew up articles of incorporation, and after long discussion united upon certain principles and statements which have formed the basis for similar organizations elsewhere. The essential features of these articles of incorporation are that they provide means for putting into effect the provisions of the reclamation law in regard to ownership of the reclaimed areas in small tracts and for guaranteeing repayment to the United States of the cost of reclamation. The property of the water users is, in effect, mortgaged to secure the repayment of the estimated cost of construction, and the requirements of the law regarding the cultivation of the land in small tracts, the appurtenance of water, and other details are carefully guarded.

The Salt River Valley Water Users' Association was, as above stated, the first organization formed, and its experience has served as a guide to others. The history of the organization is given at some length in Water-Supply Paper No. 93, pages 130–158. The first general action was taken at a mass meeting held in Phoenix, August 2, 1902, and the scope of the matters under discussion were outlined by Judge Joseph H. Kibbey in an address during the following month. An executive committee of eleven members was formed and preliminary subscriptions were obtained. The articles of incorporation were finally drafted on February 4, 1903,[a] and negotiations formally conducted with the Secretary of the Interior resulted in the drawing up of a formal contract with him June 25, 1904. (See pp. 129–133.)

The following list gives the present condition of the various water users' associations, proposed and in operation:

Arizona.—Salt River Valley Water Users' Association. B. A. Fowler, president; E. W. Wilbur, vice-president; E. J. Bennitt, treasurer; F. H. Parker, secretary. On June 25, 1904, a contract was entered into by the association with the Secretary of the Interior.

California.—Yuma County Water Users' Association. Organized under the laws of the Territory of Arizona November 2, 1903. M. Winsor, president; J. M. Thacker, vice-president.

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[a] See Second Annual Report Reclamation Service, pp. 76–87.

Colorado.—Uncompahgre Valley Water Users' Association, Montrose, Colo. Organized under the laws of Colorado May 11, 1903. J. H. Halley, president; Ira H. Monell, secretary.

Idaho.—Payette-Boise Water Users' Association, now in process of formation. J. H. Lowell, principal officer.

Montana.—Milk River Valley Water Users' Association, in process of organization, to include landowners in vicinity of Malta, Mont.

Nebraska.—The Platte Valley Water Users' Association, to be formed as soon as surveys have been completed.

Nevada.—Truckee-Carson Water Users' Association, to be formed, if necessary, upon completion of surveys.

New Mexico.—The Mesilla Valley Water Users' Association, to be formed of landowners near Las Cruces. The Rio Hondo Reservoir Water Users' Association, organized among landowners near Roswell. John W. Poe, president; Samuel Atkinson, secretary.

North Dakota.—Lower Yellowstone Water Users' Association, under Fort Buford project, now being incorporated. B. S. Adams, president; F. H. Lovering, vice-president; J. P. Meadors, treasurer; E. C. Hicks, secretary, Newlon, Mont.

Oregon.—The Malheur Valley Water Users' Association, organized to include landowners in the vicinity of Vale. C. E. Belding, president; F. W. Metcalf, first vice-president; E. F. Pratt, second vice-president.

South Dakota.—The Belle Fourche Valley Water Users' Association, incorporated July 20, 1904, to include private lands near Belle Fourche.

Utah.—The Utah and Idaho Water Users' Association, to be formed, to include lands to be supplied with water from Utah Lake.

Washington.—Palouse Water Users' Association, to be organized, to include lands near Pasco.

Wyoming.—The Shoshone (or Cody) Water Users' Association, to be formed after lands have been taken up.

SUMMARY OF OPERATIONS.

In the following pages is given a summary of the operations in each State and Territory, the technical details of which are given in later chapters prepared by the men in the field. The attempt is made by this part of the report to bring together somewhat concisely the larger facts, leaving for the detailed descriptions many of the items of local interest.

ARIZONA.

In this Territory attention was given first, under the reclamation law, to the consideration of the relative merits of the two large reservoir sites which had been previously known and widely discussed. These are the San Carlos site, on Gila River, and the Salt River site, on Salt River, the principal tributary of the Gila. The former was examined in connection with the surveys of the Buttes reservoir site, authorized by act of Congress approved July 1, 1898, appropriating

$20,000 for ascertaining the depth to bed rock at Buttes and estimating the cost of construction of a dam across the river.

In addition, general examination has been made of opportunities of storing water in various parts of the Territory and of the underground waters of Salt River Valley that may be made available by pumping. The work in Arizona is under the charge of Louis C. Hill, supervising engineer.

SALT RIVER PROJECT.[a]

This project involves the construction of a dam 240 feet high for the storage of 1,100,000 acre-feet of water and of power plants for pumping water for irrigation in the lower valley. The estimated cost of the dam and power plants will be about $3,200,000.

The dam site is on Salt River, about 70 miles above Phoenix and immediately below the mouth of Tonto Creek. Water stored at this point will be turned down Salt River and utilized on 160,000 to 200,000 acres of land in the vicinity of Phoenix. Most of the land is in private ownership, but all the surrounding public land has been withdrawn pending survey. In addition to this, it is estimated that by developing the flow available along Salt River and using it for pumping an area amounting to nearly 60,000 acres can be added to the irrigated district in Salt River Valley. The power developed along the river would be transmitted to substations properly located and there distributed at a lower voltage to pumping stations so situated as to furnish water for irrigation.

An association of the water users has been formed for the purpose of dealing with the Secretary of the Interior and guaranteeing the carrying out of the purposes of the law and the repayment of the cost of reclamation. In February, 1904, the Secretary of the Interior approved a form of contract which it was proposed to enter into with this association. This form was submitted to the association and was accepted by vote on May 10, 1904.

The locality is so nearly inaccessible that the freight on bricks, lime, and cement is practically prohibitory. Arrangements have therefore been made to manufacture these on the ground.

Following is a summary of the contracts entered into in connection with the Salt River project:

Generators for temporary power plant.—Proposals advertised for in August, 1903; bids opened September 21, 1903; contract entered into with Bullock Electric Manufacturing Company, Cincinnati, Ohio, under date of January 8, 1904.

Machinery for Portland cement plant.—Proposal dated September 18, 1903. Bids opened at Denver September 21, 1903. Contract dated December 22, 1903, with Allis-Chalmers Company, Chicago. Award approved by Secretary of the Interior October 12, 1903. Date of execution of contract by Secretary March 5, 1904.

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[a] For detailed report, see pp. 129–155.

Mill for Portland cement plant.—Contract dated December 17, 1903, with Wilcox & Rose, of Riverside, Cal. On October 12, 1903, the Secretary of the Interior authorized the award to this company and contract was executed by him on March 5, 1904.

Electric motors.—Bids advertised for in August, 1903, and opened September 21, 1903. Contract dated January 5, 1904, awarded to Hendrie & Bolthoff Manufacturing and Supply Company, Denver.

Construction of sluicing tunnel.—This tunnel is in the canyon of Salt River below the mouth of Tonto Creek. It will be about 500 feet in length, 10 feet high, and 13 feet wide, through hard sandstone and shale. Bids were opened on December 22, 1903, and all were rejected. On March 16, 1904, the Secretary of the Interior accepted the offer of John Tuttle for excavating and completing this tunnel.

Telephone line from Arizona dam to Livingstone.—Proposals advertised for in August, 1903. Bids opened September 21, 1903. Contract dated December 26, 1903, entered into with James R. Thorpe and executed by the Secretary of the Interior on March 15, 1904.

Water wheels, governor, and draft tubes for power plant.—Contract dated February 18, 1904, entered into with Stillwell-Bierce & Smith-Vaile Company, Dayton, Ohio. Award approved by Secretary of the Interior October 12, 1903.

Power canal and auxiliary works in Tonto basin.—Proposals advertised for October 31, 1903, and bids opened January 7, 1904. This work is divided into three schedules. Schedule No. 1, including excavation and certain structures of concrete, timber, and cast iron, was awarded to Robert Sherer & Co., of Los Angeles, Cal. Schedule No. 2, consisting of tunnels and lining, was awarded to John Tuttle, of San Francisco, Cal. All bids on schedule No. 3, which included alternative bids for wood-stave pipe and concrete pressure pipe, were rejected.

Cement.—On January 4, 1904, bids were opened for 1,000 barrels or more of first-class Portland cement, delivered at Globe, Ariz. Only one formal bid was received. This was rejected and purchase was made in the open market at $2.62 per barrel.

On February 29 bids were opened for 150,000 barrels or more of cement delivered at the dam. Three bids were received, of $5.70, $5.49, and $4.81 per barrel. All these bids were rejected, and a contract was entered into for the construction of a cement plant.

A waterworks system has been installed for the purpose of supplying potable water to the camp and town at Roosevelt, and the telephone line connecting the headworks of the upper power canal with the Arizona dam has been completed.

The building for the cement mill is completed, and the cement-mill machinery will probably be installed and the mill in operation early in January. The Phoenix-Roosevelt road is about finished. The final location of a power canal at the mouth of the Verde is practically complete. The cadastral survey of the irrigable lands in Phoenix Valley has been completed.

Of the 4,475.08 acres of patented lands within the extreme high-water line of the reservoir, 1,471.14 acres have been purchased at a total cost of $34,525. Contracts of purchase have been made, or understandings as to price have been reached, covering 779.64 acres more at the aggregate price of $15,500, leaving 2,372.16 acres of patented land in the reservoir site as to which no agreements of purchase have been made. With two or three exceptions these remaining tracts are of comparatively small value.

There are also 940 acres of entered lands not yet patented within the reservoir site, but no efforts have been made to obtain the interests of the entrymen, since practically all their entries are subject to one or both of the reservoir filings of the Hudson Reservoir and Canal Company, which, in 1895 and again in 1900, filed a map of location of a reservoir covering substantially the same site as the Government reservoir. This company's rights were recently purchased by the Government for $40,000.

Two tracts of school land, aggregating 240 acres within the limits of the proposed reservoir, leased under the authority of the board of supervisors of Gila County, were purchased by the board of water-storage commissioners of Maricopa County for $4,300, and afterwards, through the county of Maricopa, transferred to the Government for a nominal consideration. The purchases carried with them the unexpired term of current leases, together with improvements and water rights.

It is hoped the purchase of the land within the reservoir site not yet settled for will be consummated at an early date. Proposals for the construction of the dam will be opened February 8, 1905, and it is expected that operations will begin soon after.

Complete tests of the irrigation plants in Salt River Valley are being carried on. These include tests of steam, steam-electric, hydro-electric, and gasoline plants, ranging in capacity from 10 to 500 horsepower. The data obtained, together with the work on the underground flow, which is already completed, will furnish the basis for the design of the pumping plants which will form part of this project.

The quality of water in Salt River Valley is variable, some of it containing so large an amount of sodium chloride, or common salt, that its continued use for irrigation is detrimental to crops. It is therefore necessary to determine the amount of salt in Salt River at different stages and the proportion which the river carries at progressive points from the upper to the lower end of the valley. An examination of the ground waters in the lower valley has also been made, in order that the data might be considered in connection with the establishment of pumping stations. The investigations were carried on by S. K. Baker, hydrographic aid, under the direction of M. O. Leighton, hydrographer in charge of hydro-economic work, and occupied a period of seven months, from April to November, inclusive.

It was at first believed that the greater portion of salt in the river water was derived from one or more isolated sources above the Tonto dam site. If this were found to be true, it would probably be quite feasible to cut off these sources of contamination, and thereby diminish the amount of salt contained in the stream water. If salt springs form the source of the salt they could be plugged up; if an extensive outcrop of salt is crossed by the river it could be faced over with concrete or walled away from the stream bed. Investigation in the highlands showed that at considerable distances up the river there are two great series of salt springs and ledges covered with salt incrustations. Preliminary investigations indicate that these are not the important sources of salt, but only indicate the general character of the rocks beneath the surface throughout the entire valley. If this is the case the plugging up of springs and other measures suggested might diminish the salinity of the water immediately below these points but would have no important effect upon the lower river. The location of these springs and outcrops, too, is so remote and inaccessible, and the conditions surrounding them are so peculiar, that any effectual means to this end might be of prohibitive cost. On the other hand, studies of the effect of dilution by floods and by the sweet-water tributaries are apparently sufficiently reassuring to warrant a dismissal of anxiety so far as Salt River is concerned. It is only at low stages of the stream that the percentage of salt becomes sufficiently high to be detrimental to the irrigated products. There is no necessary injury to the soil from the application of this water, even at its highest concentration, if proper means are provided for thorough drainage.

The investigation in the lower valley, where the greater part of the water made available by the Salt River project is to be applied, was directed toward a general determination of the salinity of the ground waters. This work proved to be of great importance, as it showed definitely the areas of strong salt concentration. It has been clearly demonstrated that strongly saline water may be applied without injury to crops if the dissolved materials do not accumulate in the soil. Therefore, in connection with the application of this river water it is necessary to take into account the salinity of the soil and of the ground water and so apply the water that there shall be no such accumulation. In determining the position of wells for pumping systems the general character of the underflow must be taken into consideration and centers of high salinity avoided.

The work extended throughout the entire valley, so far as information was afforded by wells already sunk. The number of determinations was sufficient for the construction of a map on which the various centers of high salinity of ground waters could be plotted. A full discussion of the results of this investigation will appear in a later report.

SAN CARLOS PROJECT.[a]

This reservoir site is on the White Mountain Indian Reservation in Arizona, below the mouth of San Carlos Creek on Gila River. A dam at this point will impound about 240,000 acre-feet of water at a cost of little more than $2,000,000. The stored water can be turned down Gila River and taken out for use in the broad valley in the vicinity of Florence and on the Gila River Indian Reservation near Sacaton. Investigations were begun here in 1899, and deep borings for bed rock made during June of that year. The water supply is scanty, but the chief difficulty will be with the large amount of silt carried by Gila River.

Investigations of the foundation problem were begun by the Reclamation Service in February, 1903. The steam diamond drill, the pipe, and the rest of the apparatus were placed in charge of W. G. Steward, under the general direction of C. R. Olberg. The work was discontinued in August, 1903, 15 holes having been sunk to bed rock and diamond-drill cores taken therefrom. At present, observations of river flow and sediment are being continued and reconnaissance surveys are being made of possible reservoir sites on the upper Gila. A detailed topographic map has been made of the dam site, and a contour map partly made of the reservoir.

SAN PEDRO PROJECT.[b]

The San Pedro project is located in the southeastern part of Arizona, along San Pedro River, near the town of Benson, in Cochise County. It contemplates the construction of a dam below Charleston station, on the El Paso and Southwestern Railroad, for the storage of the flood waters of the river, and their diversion by means of canals for the irrigation of lands below.

No estimate can be made of the feasibility of this project until the amount of water available is known. A gaging station has been established, and an observer will continue his observations until enough data have been collected for a reasonable estimate of the probable supply.

Henry R. Evans was sent to make an investigation of this project for the purpose of determining its feasibility. Complete contour maps of the reservoir site were made. A canal line was located, and estimates of the cost of the canal, reservoir, and dam were made. It was found that it would be necessary to move the tracks of the El Paso and Southwestern Railroad for about 10 miles. The proposed line of this railroad was located, and an estimate made of the cost of removal. The total cost of moving the railroad was placed at $124,132. The estimate for the cost of storage, including rights of way, dam, removal

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[a] For detailed report see pp. 155–157.

[b] For detailed report see pp. 157–170.

of railroads, etc., amounts to about $556,000. Th
canal, including the head works, amount to $179,000
the project is thus about $735,000.

SACATON PUMPING PLANT.

W. H. Code, Indian inspector and irrigation expert, some investigations and estimates of the water supply fo about 10,000 acres of the Sacaton Indian Reservation by wells. The power for pumping this water is to be supplied of the power plants along Salt River. The estimated cost project is from $30 to $35 per acre. There seems to be no ques to the amount of underflow. The investigations of Willis T. Lee, Code, and others, seem to make it certain that a large amount of fair water is available for irrigation by pumping throughout the whole district southeast of Phœnix.

RECONNAISSANCE SURVEYS.[a]

Various reconnaissance surveys have been made in the southern part of the Territory, principally on streams tributary to Gila River. In particular, an examination of underground waters has been carried on in Salt River Valley by Willis T. Lee, under the direction of N. H. Darton. Mr. Lee has found that there are definite ancient channels filled with gravel, from which water in considerable quantities may be pumped. Some of this water is alkaline, but a great portion may be utilized for the reclamation of arid land.

A reconnaissance of the Little Colorado has been completed, but no good reservoir sites have been found. J. G. Camp, who made these surveys, made, also, an examination of Verde River with a view of finding a reservoir site for the purpose of storing some of the flood waters of Verde River. No better reservoir site was found along this river than the one near its junction with the Salt, where some investigations had already been made.

SUMMARY OF OPERATIONS IN CALIFORNIA.

In this State the principal reclamation projects under consideration are in the extreme southeast, along Colorado River; in the northern end of the State, adjacent to Oregon, and near the center of the State, in Owens Valley. Extensive reconnaissance surveys are being carried on along the headwaters of Sacramento River to obtain facts bearing upon the feasibility of a general system of irrigation from that stream and its tributaries. This work is under the general charge of J. B. Lippincott, with offices at Los Angeles.

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[a] For detailed report see pp. 170–191.

YUMA PROJECT.[a]

The Yuma project is located on both sides of Colorado River, in Arizona and California, near the town of Yuma. It is estimated that water can be carried to about 87,000 acres of valley land by gravity canals and to about 25,000 acres of mesa land by pumping.

A permanent dam will be constructed on Colorado River at the Laguna dam site, about 10 miles northeast of Yuma. As the soundings have shown that the construction of a high diversion dam is impracticable, the plans call for a dam with a maximum height of 19 feet above the bottom of the stream. The dam will be 4,780 feet long and will have a maximum width of 257 feet. It is to be of the Indian weir type, so successfully used in India and Egypt.

One of the gravest problems connected with this undertaking is the disposition of the silt, as it is not believed that an irrigation canal can be operated successfully along the Colorado unless provision is made for taking care of the sediment in the water. In order to keep the canals free of silt, large sluiceways will be constructed on both sides of the dam. The intake for the canals will be at the side of the sluiceways, and it is planned to fill the canals by drawing but 1 to 1.65 feet of water, which will be free of sediment, from the surface of the sluice. When a considerable quantity of silt has accumulated in the sluiceways, the sluice gates will be opened and the very large volume of water that will be allowed to escape will wash the sediment out of the sluiceways and into the river below. Another very difficult problem in connection with this project is the crossing of Gila River. This will be effected by means of a structure consisting of four steel-concrete pipes of large diameter.

The pumping plant for raising water to the Yuma mesa will be one of the largest in the United States. Crude oil will be used for fuel, and about 300 second-feet of water will be raised about 70 feet. This will be sufficient to irrigate about 25,000 acres of land. Pumping will also be necessary to reach about 7,000 acres in the upper Gila Valley. Here the lift will range from 5 to 25 feet. The power will be furnished by electricity generated at the mesa pumping plant.

On account of the annual rise of Colorado River and the severe floods in the Gila it has been considered necessary to construct levees in order to protect the lands from overflow, as without levees farming or residence would be practically impossible. These levees will be of essentially the same design as those in use on Mississippi River. They will be about 7½ feet high, 8 feet wide on top, and will have a slope of 1 vertical to 3 horizontal on the water side and of 1 vertical to 2½ horizontal on the land side. Altogether about 73½ miles of levees will be required.

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[a] For detailed report, see pp. 192–199.

The valley lands under the Yuma project are very rich, and it is believed that the plant food carried by the silt and in solution will fertilize the irrigated lands. The valley lands are suitable for the production of forage and grain, and the mesa lands are adapted to the growth of early vegetables and fruit, which will probably come into the market earlier than similar products from any other section of the United States.

The entire cost of this enterprise, provided all the valley lands are irrigated as contemplated, will amount to about $40 per acre irrigated. It is possible, however, that the cost may be somewhat greater or less, but an effort has been made to cover all the contingencies, and the estimates of cost have been liberal. Plans and specifications for the dam and sluiceways have been approved by a board of consulting engineers, and plans, estimates, and specifications for the other works necessary are being prepared.

OWENS VALLEY PROJECT.[a]

Owens Valley is on the eastern slope of the Sierra Nevada, in Inyo County, Cal., at an elevation of about 4,000 feet. The stream measurements during the last winter show that 199,000 acre-feet of water could be made to pass through the Long Valley reservoir site at the head of Owens Valley. It is estimated that in average years 240,000 acre-feet of water over and above the amount now beneficially appropriated will be available for storage in Long Valley. Probably from 80,000 to 100,000 acres of land can be irrigated, as compared with 30,000 under existing conditions. A drainage system will be essential, and the water thus collected from the upper end of the valley may properly be used for the irrigation of other lands in the lower end. The opportunities for developing water power, which are very great, can probably be used for pumping additional water from the saturated lands to other irrigable lands.

Stream measurements are being made on Owens River and its tributaries and on all the canals in Owens Valley. A determination is being made of the duty of water, the irrigated areas are being located and classified, and evaporation records are being kept. Preliminary surveys have been made of all the lakes and possible reservoir sites on the tributaries of Owens River entering below Long Valley, with a view of augmenting the supply of storage water from this source. This has been the principal work of the past summer. It is in charge of J. C. Clausen, with J. B. Lippincott as supervising engineer. Willis T. Lee, geologist, has reported on the volume of available ground water, on the possibility of manufacturing cement from local products, and on the character of the Long Valley reservoir site. T. H. Means, engineer of soils, has made a preliminary examination of the soils, with a view of determining the localities upon which the surplus water can best be applied.

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[a] For detailed report, see pp. 199–202.

On September 3, 1904, all surveys were discontinued for the season, owing to delays in obtaining machinery for determining the bed-rock conditions at the Long Valley dam site. Elaborate surveys will not be made prior to this determination, because if it be unsatisfactory the entire project will fall.

KLAMATH PROJECT.[a]

Klamath River is the outlet of Klamath Lake, Oregon. It flows through large swamp areas in Klamath County, Oreg., and by an overflow process feeds Little Klamath Lake, on the Oregon-California boundary. After issuing from Little Klamath Lake, it flows southwestward through Siskiyou, Humboldt, and Del Norte counties, Cal., and empties into the Pacific. In this lake region irrigation is essential to successful agriculture. The lands are flat, and the soil is a fertile, sandy loam and can probably be irrigated at relatively small expense. It is estimated that 140,000 acres can be irrigated from Klamath River, 72,000 additional from reservoirs, and about 100,000 in Butte Creek Valley by pumping. About 1,104,000 acres under this project have been segregated.

The basin of Klamath River was visited by John T. Whistler, engineer, in October, 1903, who reported on November 2, 1903. H. E. Green, engineer, also visited the basin in October, 1903, and reported thereon. These reports were preliminary and were considered sufficient justification for a further investigation into this section during the present summer. For this purpose T. H. Humpherys, assistant engineer, reporting to J. B. Lippincott, supervising engineer for California, was detailed to the work in May, 1904. Topographic surveys are being made of the Horse Fly reservoir site and the Clear Lake reservoir site, under the direction of F. S. Chapman. The latter of these may cover 20,000 acres.

F. K. Lowry is making a topographic survey of Klamath River near Keno, Oreg., with a view of determining the possibilities of lowering and draining Lower Klamath Lake. An angle line survey is also being made of the existing canal systems, with a view of utilizing them in the general project. Gaging stations have been established on Lost River at Clear Lake and at its entrance to Tule Lake, on Link River at Klamath Falls on Klamath River at Keno, and on Miller Creek at the Horsefly reservoir site. Records of precipitation, lake fluctuations, and evaporation are being maintained on the Klamath lakes and on Tule Lake. A line of levels is being run from the Geological Survey bench mark on the Southern Pacific Railroad to Klamath Falls.

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[a] For detailed report, see pp. 202–213.

A reconnaissance of the swamps (said to contain some 90,000 acres) on the Williamson River, in the Klamath Indian Reservation will soon be made, and transit canal lines will be run to determine possible positions for canals and to ascertain the irrigable areas in the valleys that may be reclaimed under this system. Soundings are to be made of Lower Klamath and Tule lakes, to determine the extent to which they may be drained. It is hoped that these soundings and the examinations of the lake beds can be carried on during the winter through the ice.

SACRAMENTO VALLEY PROJECT.

Sacramento Valley is the northern portion of the great central valley of California. It contains 4,196 square miles, and the total area of its basin, including its mountainous portions, is 26,187 square miles. The water supply is very great, particularly from the northern and eastern portion; from 1878 to 1885 the mean annual discharge, as measured at Collinsville, was 25,936,000 acre-feet. The valley is very fertile, but its southern portion is subject to extensive overflow. In March, 1904, 800,000 acres were flooded.

The investigations of Sacramento Valley contemplate the general reconnaissance of the entire basin of the river, the search for reservoir sites, the gaging of streams, and the approximate determination of the areas of irrigable land. The work is being carried on in cooperation with the State of California, and also in harmony with the work being done by the topographic branch of the Geological Survey, which is mapping the valley lands, and the Bureau of Forestry of the Agricultural Department, which is examining the forest reserves.

Up to the present time the western side of the drainage basin and the northern portion of the basin as far as Pit River, inclusive, have been examined and reservoir sites surveyed. Sites have been found that aggregate in estimated capacity 1,800,000 acre-feet. Eight gaging stations have been established and maintained at the desirable reservoir sites during the last year by J. B. Evans, hydrographer, who has been assigned to the work.

Attention is called to the report by A. E. Chandler, contained in Water-Supply Paper No. 45, entitled "Water Storage on Cache Creek, California," and to Water-Supply Paper No. 86, by Burt Cole, entitled "Storage Reservoirs on Stony Creek, California." These extended reports deal with tributaries to Sacramento River.

Stream measurements have been made on a large number of tributaries to the Sacramento, the gaging stations usually being located at dam sites. Estimates have been made by H. E. Green, engineer, on the cost of constructing dams on Putah Creek and on Sacramento River at Jellys Ferry.

S. G. Bennett, engineer, has been placed in charge of the field investigations of the Sacramento Valley project, with L. M. Lawson, assistant engineer, and J. B. Evans, field assistant, in charge of topographic parties. These parties have completed surveys of large reservoir sites in the basin of Pit River, a tributary of the Sacramento. The following were surveyed: Big Valley at Bieber, Round Valley at Adin, Warm Springs Valley at Canby, Jess Valley at Adin, and West Valley near Ivy. A topographic survey was made of the outlet of Goose Lake, and preliminary soundings were made to determine the possibility of draining off a portion of the water and reducing the area exposed to evaporation. The water thus saved could be used for irrigation in the vicinity of Alturas, Cal. The work of sounding Goose Lake will be continued this winter if the ice becomes thick enough to support a sounding party.

STREAM MEASUREMENTS.

The State of California has made an appropriation providing for cooperation in the stream gaging, $15,000 being available for two years from July 1, 1903. Sixty-seven gaging stations are being maintained in the State, those on the Colorado, Owens, and upper Sacramento being directly in connection with reclamation projects. The stream-gaging work is in charge of W. B. Clapp, engineer.

SUMMARY OF OPERATIONS IN COLORADO.

In this State special attention has been devoted to the Uncompahgre Valley project. Surveys have also been conducted looking to the reclamation of lands in the northwestern part of the State by waters from White and Yampa rivers. An examination has been made of the opportunities for reclamation of land near Grand Junction, Colo., and in addition reconnaissance has been carried on in various parts of the State. The work is under the general charge of A. L. Fellows, with offices in the Chamber of Commerce Building at Denver.

UNCOMPAHGRE VALLEY PROJECT.[a]

This project is located in Montrose and Delta counties, in western Colorado, on the western side of the main range of the Rocky Mountains. The water supply is from Gunnison and Uncompahgre rivers, from the former of which it is expected that water will be taken by means of a tunnel about 6 miles in length, beginning in the Grand Canyon of the Gunnison and ending in Uncompahgre Valley a few miles northeast of the town of Montrose. From the lower portion of the tunnel the water will be taken around the edge of the valley for the purpose of irrigating about 125,000 acres of land, a considerable part of which is in private ownership in small tracts. It is estimated that this project will cost in the aggregate approximately $2,500,000 and that it will take four years to complete it. The first withdrawal of land, comprising about 137,000 acres, was ordered January 31, 1902, before the passage of the reclamation act. On October 24, 1902, an additional area of 238,000 acres was withdrawn. Since that date there have been returned to general entry about 46,000 acres, and the return to general entry of about 125,000 acres additional has been recommended. The lands to be irrigated are in the vicinity of the towns of Montrose and Delta and are traversed by the narrow-gage branch of the Denver and Rio Grande Railroad. The principal crops raised are fruits, grains, alfalfa, and vegetables.

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[a] For detailed report, see pp. 214–227.

Preliminary examination was begun by the United States Geological Survey in 1901. Surveys were continued after the passage of the reclamation act in 1902, and a preliminary report was made March 7, 1903. This was submitted to a board of engineers consisting of Messrs. A. P. Davis, J. H. Quinton, and Morris Bien, and was favorably indorsed by them, further examination being ordered. Accordingly topographic surveys of the land affected have been made on a scale of 1,000 feet to the inch, and precise surveys for the purpose of definitely locating the tunnel and headworks have been concluded.

A detailed report was submitted to the chief engineer on January 25, 1904, and on May 8, 1904, a board of consulting engineers consisting of Messrs. A. P. Davis, G. Y. Wisner, and W. H. Sanders, accompanied by Morris Bien, engineer, and Prof. L. G. Carpenter, State engineer of Colorado, considered the report and went over the proposed tunnel locations and canal lines and reported favorably concerning the construction of the project. In accordance with this report the sum of $2,500,000 was conditionally set apart by the Secretary on June 7, 1904. Final acceptance, however, depended upon compliance with conditions regarding lands in private ownership imposed by the board of consulting engineers, all of which conditions have now been met.

On June 16 the officers of the Uncompahgre Valley Water Users' Association met the chief engineer at Denver and reported to him as to existing conditions. A resolution was adopted, with the chief engineer's consent, authorizing the secretary of the association to close the subscription books as requested.

On June 27 the chief engineer visited Montrose and was again met by the officers of the Uncompahgre Valley Water Users' Association, who reported that the conditions set by the consulting board had been substantially complied with, and offering, on the part of the principal citizens of Montrose and Delta counties, to sign a bond for any amount that might be desired, guaranteeing to the

Government the return of any money that might be spent in a preliminary way in construction in case the conditions were not fully met. Such a bond, in the sum of $75,000, was signed later. At the present time, however, the conditions concerning subscriptions have been more than met, about 95,000 shares of stock being subscribed for, whereas but 80,000 were required. With the Government land available, the irrigable lands under the project will amount to about 125,000 acres.

July 10 to 13 a board consisting of W. H. Sanders, G. Y. Wisner, and J. H. Quinton, consulting engineers, drew up plans and specifications for the main tunnel and a portion of the main canal, and on July 13 recommended that bids on the tunnel and a portion of the main canal be asked for.

The topographic map of the lands under the project has been completed on a scale of 1 inch to 1,000 feet, with contour intervals of 10 feet. Final locations are being made and final estimates are being prepared. Paper locations of tunnel and main canal have been completed and a considerable part of the system has been located upon the ground. A road is being constructed across Vernal Mesa, joining the two ends of the proposed tunnel. A telephone system has been devised and bids for its construction have been obtained.[a] Bids have also been obtained for the construction of a portion of the main canal and the main tunnel.[b] Plane-table surveys of reservoir sites that may be utilized later are being carried on along the headwaters of Gunnison River.

GRAND RIVER PROJECT.[c]

This project at present contemplates the reclamation of approximately 60,000 acres of land in the vicinity of Grand Junction, on Grand River, in Mesa County, Colo., the water to be taken from Grand River about 20 miles above the town of Grand Junction. Preliminary examinations of this project have been made for a number of years past by local engineers, and in June, 1902, investigations under the reclamation act were ordered by the chief engineer, and Gerard H. Matthes was placed in charge of the work. On July 2, 1902, about 400,000 acres were withdrawn, but after investigation by Mr. Matthes 170,000 were returned to general entry as being outside of the limits of the project.

During the season of 1902 and the winter of 1902-3 preliminary surveys were made under the direction of Mr. Matthes, with a view to constructing a canal high enough to reach a large tract of land aggregating over 200,000 acres in Colorado and Utah. This was found to be not feasible, however, and an examination by the board of consulting engineers, consisting of A. P. Davis, G. Y. Wisner, and W. H. Sanders, resulted in the condemnation of this high line and in a recommendation that a lower line be surveyed, which it was believed would be found feasible for the irrigation of the 60,000 acres in Mesa County above mentioned.

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[a] See pp. 221-224.

[b] See pp. 216-219.

[c] For detailed report, see p. 227.

No field work has as yet been done on this project in 1904, and it is not expected that any will be carried on during the remainder of the year. This is due to the fact that an irrigation district has been formed under the laws of the State of Colorado, through which the construction of the project by private capital is contemplated. It is not proposed that any work shall be done on this project so long as it is under serious consideration by local capitalists. It is thought, however, that the project is a very worthy one, and the board of consulting engineers and the district engineer have recommended that, if it is impracticable for private capital to handle the situation, the Reclamation Service should again take hold of the project.

WHITE RIVER PROJECT.[a]

It is proposed to reclaim approximately 90,000 acres of land in northwestern Colorado, in Rio Blanco and Routt counties, the water to be taken from White River about 30 miles above the town of Meeker. Preliminary examinations of this project were made by A. L. Fellows, first in 1898 and again in 1901. Investigations under the Reclamation Service were ordered by the chief engineer in May, 1903. In June of that year Robert S. Stockton was placed in charge of this work. On February 9, 1903, about 377,000 acres were withdrawn (exclusive of the White River Forest Reserve), but on August 13, 1903, after investigation by Mr. Stockton, 170,000 acres were returned to general entry as being unsuited for irrigation, and 90,000 acres were added to the former segregation. It is estimated that the cost of the project will be approximately $2,000,000.

During the season of 1903 reconnaissance surveys were carried on over the entire area and material was obtained for a preliminary report. Field work was brought to a close November 16, and Mr. Stockton, engineer in charge, returned to Denver. He was employed throughout the winter in making preliminary estimates with reference to the project.

The locality will probably be visited by the board of consulting engineers, who will consider the preliminary report and conditions and decide as to whether further work shall be taken up or not.

COLORADO RIVER STORAGE PROJECTS.

As it has been thought necessary to store water in the Rocky Mountain region for the regulation of the flow of Colorado River, with a view to the reclamation of about 600,000 acres of land along the lower Colorado in Arizona and California, certain reservoir sites have been withdrawn in western Colorado, two of these being on Grand River, in Grand County, and two on Yampa River, in Routt County. Preliminary examinations have been made of all these sites, and some of them have been surveyed.

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[a] For detailed report, see pp. 228–229.

KREMMLING RESERVOIR SITE.[a]

This site, by far the most important of all the sites thus far withdrawn for the purpose of assisting in the reclamation of lands on the lower Colorado, is located in the western part of Grand County and covers an area of about 14,000 acres at the 181-foot contour. It has been estimated that its storage capacity is about 1,500,000 acre-feet. Lands covering this site, amounting to 39,680 acres, were withdrawn May 12, 1904. No work except of a reconnaissance character has been carried on by the Reclamation Service in regard to this site, all the data available being derived from surveys made by local capitalists interested in the development of power. It is not expected that surveys of the site will be made until claims of both this power company and contesting railroads have been settled. It is not probable that any work will be done on the project in the immediate future.

GRAND LAKE.[a]

This lake, located in the northeastern part of Grand County, Colo., was withdrawn for examination in June, 1904, the area set apart being 23,040 acres. No survey except of a reconnaissance character has been made of the lake, and it is not expected that any will be made this year. The land about the lake is practically all owned by private individuals, the lake being used as a pleasure resort.

YAMPA RESERVOIRS.[b]

Two reservoir sites have been located on Yampa River, in Routt County, both of which have been surveyed. A reconnaissance examination has also been made of a third site. In June, 1904, the lands were withdrawn by order of the Secretary of the Interior, the area set apart being about 100,000 acres.

RECONNAISSANCE SURVEYS.

In addition to surveys and examinations which may lead to early construction, expenditures have been incurred in looking after various projects of interest to the public. Exploration has been made in western Colorado and considerable time devoted to a thorough examination of several projects in other parts of the State which have been popularly considered to be of importance. Further work of this character is now being carried on.

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[a] For detailed report, see p. 229.

[b] For detailed report, see p. 230.

SUMMARY OF OPERATIONS IN IDAHO.

In this State there are a number of projects for the reclamation of arid land, both in public and private ownership. The most important of these is the so-called Minidoka project, on Snake River below American Falls, where the lands are almost entirely public, and the Payette-Boise project, in the southwestern part of the State, where the lands are mainly in private ownership. The latter may be reclaimed by storage and control of the waters of the Payette and Boise rivers. A third project is in the southeastern part of the State near the headwaters of Snake River, where a vast extent of desert public land can be reclaimed by storage of flood waters if suitable reservoirs can be found. The work is under the general direction of D.W. Ross, with offices in Boise.

MINIDOKA PROJECT.[a]

This project is located on Snake River in the southern part of Idaho, where it is proposed to reclaim about 130,000 acres of desert land belonging to the United States. Water is to be taken from Snake River, the dam being located about 40 miles below American Falls and 6 miles south of Minidoka station on the Oregon Short Line Railroad.

The lands to be reclaimed were withdrawn by order of the Secretary of the Interior dated November 17, 1902. Preliminary surveys were begun in March, 1903, and the preliminary estimates and reports were filed with the chief engineer in October, 1903. All the trial surveys have been completed and a plane-table survey on a scale of 1,000 feet to the inch has been made of 130 square miles on the south side of the river, at the approximate cost of $40 per square mile. A classification has been made of about 120,000 acres on both sides of the river. A topographic survey has been made of the dam site on Snake River and of 7 miles of the upper portion of the north-side canal. The field work was brought to a close in the early part of December, 1903, and during that month plans of several of the different structures were made. Assistance in preparing these plans was given by J. H. Quinton, consulting engineer.

A field party was put to work the first week in February, 1904, in making surveys for the final location of the canal system covering the north-side lands. Many preliminary lines for this purpose were run, and the control work for a topographic survey of the north-side tract, consisting of about 60,000 acres, was completed.

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[a] For detailed report, see pp. 231–237.

A board of consulting engineers, consisting of A. P. Davis, George Y. Wisner, and H. N. Savage, visited this work from March 16 to 22, and on March 21 submitted a report to the chief engineer approving the project and recommending that the Secretary of the Interior be requested to set aside $2,600,000 from the reclamation fund for the construction of the works proposed. This recommendation received favorable action, and shortly thereafter advertisements were inserted in leading engineering and construction journals of the country inviting bids for the construction of the works to be let under the first contract. On July 2, 1904, bids for the construction of dam, spillway, forebay canal, etc., were opened at Boise by the chief engineer. Seventeen bids were submitted, the lowest being that of N. J. Blagen, of Portland, Oreg., the second lowest being submitted by the Bates & Rogers Construction Company, of Chicago, Ill. Mr. Blagen failed to qualify for the contract and it was awarded to the Bates & Rogers Construction Company. On July 19, 1904, bids were invited for furnishing 14,000 barrels of Portland cement to be used in the construction of these works. Four bids were opened at Boise on August 25, the Utah Portland Cement Company being the lowest bidder.

Many preliminary lines have been run on the north side of the Snake River with a view of ascertaining the most feasible route for the location of the main canal. Owing to the level yet somewhat broken character of the country and the fact that a great deal of rock would be encountered in construction, many alternative lines had to be run and estimates made before the cheapest and best route was found. This work has been finished and a definite route decided upon. From 800 to 900 feet of test pits, from which material for back filling for the dam will be taken, have been dug in the vicinity of the dam site and along the line of the fore-bay canal and tailrace from the power house. Several alternative sites have been investigated for a power house and tailrace.

The irrigable lands have been surveyed on a scale of 1,000 feet to the inch, with contour intervals of 1 and 2 feet. This survey serves as a basis for locating the distributing system over this area, and is being made with great precision, there being but little latitude in the matter of grades, etc., as the surface is very flat.

It has been recommended that at least two town-site reservations be made along the line of the location of a proposed branch of the Oregon Short Line Railway, which leaves the main line at Minidoka and bisects the irrigable lands of the project. On April 15 a recommendation to the Secretary of the Interior was made by the Director of the Geological Survey to the effect that certain tracts near points selected for sidings on this proposed railroad by the Oregon Short Line officials be withdrawn from all entry, and held for town-site purposes. In pursuance of this recommendation an order was sent to the local land office at Hailey, Idaho, temporarily withdrawing from entry the two townships embracing these subdivisions until such time as a description of the lands could be sent to that office by mail. On May 2 a proclamation was issued by President Roosevelt, confirming the action of the Secretary, and reserving these tracts, three in number, for town-site purposes. Plats showing farm-unit classifications of the irrigable lands under this project have been prepared for filing in the local land office.

The topographic survey of the land on the north side of Snake River was completed in August, and the plane-table parties were transferred to the Payette-Boise project. The locations of the fore-bay canal and the main north-side canal were determined and preliminary location was fixed for the south-side canal. Careful investigations were undertaken for the location of the power house at the end of the fore-bay canal. Visits were made to the site by H. A. Storrs and O. H. Ensign, electrical engineers, who approved the general plan for power development. Surveys were also made of the land which will be flooded by the backwater of the dam and a report on improvements and probable damages prepared. With the assistance of A. J. Wiley, consulting engineer, plans of structures were revised where necessary and details worked out for actual construction.

Work is now in hand in projecting and laying out the distributing system on the north side of the river and on the final location of the main south-side canal; also on plans and estimates covering the second division of the work, which will probably embrace the entire canal system on the north side of the river, with a view of letting a contract for it early during the coming winter. Actual construction on the dam and spillway began during November and will probably be continued during the entire winter.

PAYETTE-BOISE PROJECT.[a]

This project contemplates the reclamation of about 300,000 acres of land in the Boise and Payette valleys, in the southwestern portion of Idaho. Most of this land is in private ownership in relatively small tracts, about five-sixths of the area being at present without facilities for irrigation. The area is in or adjacent to Snake River Valley and is traversed by the Oregon Short Line, the Boise, Nampa and Owyhee, and the Idaho Northern railroads.

Temporary withdrawal of public lands, pending survey, was made by order of the Secretary of the Interior dated March 5, 1903. Preliminary or trial surveys were begun in November, 1902, and brought to a close in September, 1903. Water for the proposed project will be obtained from Boise River by utilizing the floods of that stream, the low-water flow being already entirely appropriated. The supply will be reenforced from Payette River by means of a canal carried along the bluffs on the south side of that stream and over or through the ridge dividing the two valleys. Considerable interest in this project has been shown by the landowners of these valleys, meetings being held at many points in the vicinity during December and January, 1903–4. A delegate meeting was held at Nampa on January 10, when the chief engineer of the Reclamation Service outlined the policy of the Department regarding projects of this nature and gave advice as to the necessity of perfecting some kind of an association through which to deal with the Government. Steps were at once taken in this direction, and an organization committee was formed, which has circulated petitions among the landowners, held several public meetings, and worked up a general interest in the undertaking.

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[a] For detailed report, see pp. 238–257.

Early in March petitions, lists of lands, and plats showing location of irrigable land under the project were forwarded by the organization committee to the Secretary of the Interior, with a request that the preliminary examination of the project be extended and completed, and funds set aside for the construction of the necessary works, construction to be commenced upon the perfecting of an organization of landowners approved by the Secretary. The landowners were encouraged in their effort to perfect the necessary organization, and surveys were continued with a view of ascertaining the feasibility of the project.

Several meetings have been held by the organization committee of the landowners, at one of which articles of incorporation were presented, and a board of directors, consisting of 11 members, was named to act for the first year. These articles were prepared by Hon. J. H. Richards, of Boise, and forwarded to the Department for examination and criticism.

Surveys have been made of the main canal lines of this proposed system. Two field parties have been engaged, one under the direction of Charles B. Smith, assistant engineer; the other under the direction of G. H. Hogue, assistant engineer. Surveys for the main canal were completed August 25, 1904, and plane-table parties organized to prepare line topography on a scale of 400 feet to 1 inch, with contour intervals of 5 feet, and of dam sites, points of diversion, and locations where work is likely to be somewhat difficult in greater detail. This topographic work has been completed and the preparation of plats and estimates will be made.

Further investigations have been made of the storage possibilities on Boise River and on Payette drainage. The investigations made by Fred Stockton, assistant engineer, in the vicinity of Payette lakes, indicate that it will be entirely feasible to utilize Big Payette Lake for storage purposes, it being possible to reduce the level of the lake 25 feet by means of a short tunnel or cut about 1,600 feet long, and to raise it 5 feet by means of a dam. This can be done at comparatively small cost and will give a storage capacity of from 120,000 to 140,000 acre-feet, considerably more than will be required on Payette River. The investigations made in connection with this project point to its entire feasibility. More than 300,000 acres of desert lands of first-class quality can be reclaimed by it.

It is proposed to prepare plans and estimates of the principal structures and canals of this enterprise. The landowners, who are now perfecting a water-users' association, will enter into necessary contracts required by the Department.

DUBOIS PROJECT.[a]

This project is located in the upper portion of Snake River Valley, southwest of Dubois, in Blaine and Fremont counties, Idaho. It is proposed to reclaim about 200,000 acres of desert land belonging to the United States, by means of a large canal heading on South Fork of Snake River, near St. Anthony. The land is nearly level and is near the lower end of the sinks of Little Lost River. It is traversed on the east by the Utah and Northern Railroad.

The land was withdrawn pending survey by orders of the Secretary of the Interior, dated June 11 and July 16, 1903. Reconnaissance and trial surveys were begun in June and ended on November 10, 1903. In all 1,570 miles were covered by reconnaissance work, 369 miles in canal line location, and 116 miles in connection with reservoir surveys. The preliminary examination is not finished and will require another season.

The field parties were disbanded early in November, and in December the work was transferred to the Boise office, where maps of all the surveys made have been prepared by James G. Camp, assistant engineer, and R. J. Newell, engineering aid. The canal and reservoir surveys have been platted on standard sheets and all maps necessary for the further investigation of this project have been prepared. James G. Camp, assistant engineer, has been engaged in making surveys of storage basins on North Fork of Snake River and its tributaries. He has continued these investigations over onto the South Fork, with a view of diverting the water of this branch into the Fall River drainage. Mr. Camp states that, in his opinion, it will be entirely feasible to convert Lewis and Shoshone lakes into a reservoir, and to construct a canal from a point a short distance below Lewis Lake, to divert the water of the South Fork into the North Fork drainage. If this plan should prove feasible, it would then be possible to utilize the flow of the South Fork on the lands in the vicinity of St. Anthony and the Dubois tract, or on the lands tributary to the South Fork of Snake River, or both. The conditions at this point will perhaps determine the feasibility of the Dubois project. It will, at any rate, solve the problem of water supply for the lands tributary to the North Fork drainage.

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[a] For detailed report, see pp. 257-259.

Withdrawals of the different sites suitable for reservoir purposes have been made from time to time. These withdrawals, together with the withdrawals of irrigable lands, will serve to protect this project and render it feasible to take up the work of construction when deemed advisable.

RECONNAISSANCE SURVEYS.

Examination has been made of possible reservoir sites on the headwaters of Snake River in Idaho and in western Wyoming. Considerable work has been done since December 1, 1903, in the preparation of a general map showing the development of irrigation in Idaho. Investigations made by the Reclamation Service will be shown on this map, and the irrigation surveys now in progress under the direction of the State engineer will be indicated.

During April, 1904, Fred Stockton made a reconnaissance looking into storage possibilities on the tributaries of Malade River in the vicinity of Malade in Oneida County; during the latter part of May he made a reconnaissance of the headwaters of Big and Little Wood rivers in the vicinity of Hailey, and during July he made a reconnaissance looking into the storage possibilities on North Fork of Boise River, continuing it on the North Fork of the Payette in the vicinity of Big Payette Lake.

In July a field party was organized under charge of R. J. Newell, engineering aid, to make reservoir surveys on Big and Little Lost rivers, Big and Little Wood rivers, Birch, Medicine Lodge, and Camas creeks. Investigations have been finished on all but the last of these streams. This party has also examined the irrigation situation on the Fort Hall Indian Reservation and the conditions on the headwaters of Blackfoot River, and considered the possibility of diverting a part of this drainage into Portneuf River.

This reconnaissance work has been completed and practically the entire Snake River drainage covered by reconnaissance surveys, so that data are now at hand for reports on the irrigation possibilities of nearly every tributary valley of Snake River, except a few small valleys joining the river on the south side.

SUMMARY OF OPERATIONS IN KANSAS.

UNDERFLOW INVESTIGATIONS.[a]

The region under investigation is the drainage basin of Arkansas River, extending from Garden, Kans., westward toward the State line. South of the river channel there are 5 to 10 miles of sand hills. There are usually 2 or 3 levels of bottom lands, while north of the bottom lands and south of the sand hills is the elevated flat area known as the " High Plains." For a number of years the bed of the Arkansas has been dry during the summer months. Irrigation during July and August has been practically confined to the bottom lands, where some water has been recovered by pumping.

The investigation of the underflow of Arkansas River was begun June 11, 1904. The work consisted in accurately mapping the water plane within a distance of 6 to 10 miles from the river channel, and in making observations by the electrical method of the rate of movement of the underflow. The slope of the water plane has been found to be between 7 and 8 feet to the mile in a general easterly direction, and from 2 to 3 feet to the mile toward the river channel from the country immediately to the north and south. At the first set of underflow stations, which extended in a north-south line about 2½ miles west of Garden, the velocities of the ground water were found to be remarkably uniform, varying between 8 and 11 feet per twenty-four hours. The gravels, except occasional layers of silt, were exceedingly uniform in size and character of grain. The stations at which the determinations were made extended from the edge of the sand hills on the south to a distance of about 2 miles north of the river channel.

Similar determinations have been made at a series of stations near Sherlock, Deerfield, and at points near Lakin and Hartland. The results differed little from those obtained at the earlier stations, except that more sorting of the gravels has taken place at these latter points, giving greater variety to the rate of movement. The usual velocities vary between 6 and 24 feet for twenty-four hours, the average being not far from 10 feet per twenty-four hours.

The quantity of ground water that is passing downstream is so great and the water passes through the gravels so freely that there is no surplus left to form surface streams or to form a perennial supply for Arkansas River.

The average rainfall upon the very flat catchment area near Garden is about 20 inches per year. A very large part of this must pass into the open and porous soils, so that the actual contribution to the underflow must be considerable. If the gravels beneath the plains were not so coarse and so deep and wide, the seepage waters would be obliged to seek release in surface streams. But the underground conditions are such that ample drainage is offered by porous beds of gravel several hundred feet in depth.

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[a] For detailed report, see pp. 280–290.

The work done thus far indicates that the water of the Arkansas underflow has its origin in the rainfall upon the sand hills to the south and upon the bottom lands and plains to the north. A few plains streams like Bear Creek entirely disappear as surface streams before the Arkansas is reached. A noteworthy feature of the underflow is the lack of any natural north or south limitation to it. The velocities at the edge of the sand hills on the south and at considerable distances from the river channel on the north are about the same as near the bed of the river. There is nothing surprising in this, but it shows that it is impossible to place any north or south limit to the eastward-moving ground waters.

The investigation has shown that in time of flood Arkansas River contributes water to the underflow. The movement of the ground water away from the river channel was measured during high water and found to be 12 feet for twenty-four hours.

Existing pumping plants which supply water for irrigation along the Arkansas have been carefully tested. The cost of pumping is low on account of the very large amount of water obtained when the water in the wells is lowered only 5 to 7 feet.

It is proposed to design a gravity infiltration gallery to collect the underflow waters for irrigation and to make as careful estimate of its cost and the amount of water recoverable as the circumstances will permit. An alternative plan of recovery by pumping will be used as a basis of comparison as to cost of water recovered. When these estimates are completed, a judgment can be formed as to the practicability of the recovery of the underflow on a large scale.

SUMMARY OF OPERATIONS IN MONTANA.

In Montana principal attention has been given to the possibilities of reclamation of lands along Milk River, in the northern part of the State. In addition a reconnaissance has been made on the rivers to the south, namely, the Marias, Sun, Teton, and Madison, and preliminary surveys have been carried along some of the rivers between the Missouri and the Yellowstone. Examinations have also been made of the opportunities of development on the lower Yellowstone, as described under the heading of North Dakota.

MILK RIVER PROJECT.[a]

Milk River rises in the undulating foothills of the Rocky Mountains, near the boundary line between Montana and Canada. Its headwaters flow northeastward into Canada, and the stream continues for about 100 miles eastward parallel with the international boundary and then turns southeastward, passing through the northern part of Montana and emptying into Missouri River.

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[a] For detailed report, see pp. 291–307.

The valley through which Milk River passes is broad and contains many thousand acres of excellent arid land. The summer flow of the stream is not sufficient for the irrigation of any considerable part of this area, and it has been proposed to reenforce the supply by turning into the headwaters of Milk River the abundant waters of the St. Mary basin, immediately adjacent to the source of Milk River.

In order to avoid passing through Canada, this can probably be done by an expensive line turning southward across the head of Milk River and emptying into Cutbank Creek, a tributary of Marias River. From the latter the water may be taken into the Milk River Valley and kept in Montana throughout its course. The Milk River project is divided into three sections—the St. Mary subproject, the Marias subproject, and the lower Milk River project. The progress of the work in connection with each project will be described under appropriate headings.

ST. MARY SUBPROJECT.

St. Mary River rises on the eastern slope of the main range of the Rocky Mountains. It flows northward into Canada, its waters finally reaching Hudson Bay. Owing to the heavy snowfall in the basin, the annual run-off is large. It is proposed to store this water in St. Mary lakes, in order that it may be used to increase the supply for Milk River Valley, if it can be successfully diverted. The examinations made indicate that, at a cost of approximately $2,000,000, the water could be stored and taken to Cutbank Creek, a tributary of Marias River.

Investigations were first started on this project in 1900, work around St. Mary lakes being under charge of G. H. Matthes. During the year 1901 Cyrus C. Babb was placed in charge, and the investigations have since been under his direction. Work was continued during 1902 and 1903, and covered investigations of water supply, canal surveys, detail surveys of reservoir dam sites, and borings for bed rock at the St. Mary dam site.

Maps and estimates have been prepared for the location of the dam site and canal. These maps are on scales of from 50 to 400 feet to 1 inch. Plans for the dam have also been prepared.

MARIAS SUBPROJECT.

This is the second principal subproject for increasing the water supply from St. Mary lakes. The water diverted into Marias River must be taken out by means of a dam located in the canyon of Marias River and a large canal crossing the divide to the Milk River drainage. The board of consulting engineers has reported favorably on the general scheme as proposed—that is, the building of a 190-foot earth dam and a canyon diversion canal 17.4 miles long. Diamond drill borings have been made at the dam site and have proved satisfactory. A reservoir site, known as Lonesome Lake, has been discovered between the Marias and Big Sandy Creek, in which 208,000 acre-feet can be stored at a low cost. The estimated area under the project is 250,000 acres.

LOWER MILK RIVER PROJECT.

It is proposed to utilize the stored waters of St. Mary lakes, as brought down through the Marias River and supplemented by the natural flow of Milk River, on the arable lands of the latter stream. The country ranges in general elevation from 2,150 to 2,400 feet, and it is better adapted to irrigation than the plateau region in the vicinity of St. Mary lakes. Through the development of the broad scheme of utilization of the stored water of St. Mary River, from 250,000 to 350,000 acres can be irrigated. By depending on Milk River alone and storing in Bowdoin reservoir the two years' minimum run-off of Milk River, sufficient water for 68,500 acres will be available.

The estimated cost for this amount of land, including the Dodson diversion dam, the Malta canal, the Bowdoin reservoir, and the distribution system from the latter is $1,372,607.

In August, 1902, surveys were commenced in this section. The natural flow of Milk River and the increased supply can be best utilized by providing accessory storage. For this purpose a depression north of Lake Bowdoin, located about 8 miles east of Malta, on the south side of Milk River, has been examined. It is a broad, shallow lake of somewhat alkaline water. A survey of this locality was made in 1902, with a view to its possible use as a reservoir site.

Lake Bowdoin has already been filed upon by private parties, and to utilize it arrangements must be made for its purchase or condemnation. It will be necessary to move about 9 miles of the Great Northern Railway.

During the field season of 1903 detailed engineering surveys were made, extending from Chinook to Glasgow. The work comprised surveys of the dam site, the reservoir site, and the canal lines, and diamond-drill borings at the Dodson dam site. Investigations were made regarding questions of land titles and rights of way.

Plans and estimates have been prepared for the lower Milk River diversion, with the idea of utilizing Milk River water only. This will be feasible at a cost of from $20 to $25 an acre, even if the waters of St. Mary River can not be brought down. As stated above, 68,500 acres can be reclaimed with this restricted supply.

Field work is practically completed under the Dodson diversion system. A cross section has been made of the feed canal from the Dodson dam to the Bowdoin reservoir. Preliminary survey of the Bowdoin north canal and Bowdoin south canal, extending from Bowdoin Lake as far as Glasgow, on respectively the north and south sides of Milk River, are completed. The survey of the reservoir site and dam sites on upper Beaver Creek have also been completed.

Examination of the field sheets of topographic surveys west of Havre shows that there is a reservoir site 30 miles northwest of Havre, known as Chain Lakes reservoir site. Three parties have been moved to that vicinity, where investigations will soon be completed. Another party is surveying a canal on the south side of Milk River, heading near Chinook, and extending through the Fort Belknap Indian Reservation.

From September 12 to 19 a board of consulting engineers went over the entire area from St. Mary Lakes to lower Milk River. Their report is to the effect that owing to the discovery of the Chain Lakes site the Milk River project looks more feasible than ever before The total area available for irrigation in the Milk River Valley is 270,000 acres.

This board also met the officials of the Great Northern Railway to consider the change of tracks of this road around Lake Bowdoin and in the vicinity of Dodson diversion dam. The railroad engineers were not authorized to make a statement of the policy of the road regarding the division of cost. This matter will have to be taken up directly with the president of the Great Northern Railway.

The chief engineer and the district engineer recently held a conference at Lethbridge, Canada, with officers of the Canadian Northwest Irrigation Company in regard to the international diversions of Milk River in the United States and Canada. No definite results were reached, but a clearer understanding of the question on both sides was obtained.

SUN RIVER PROJECT.[a]

Sun River receives the drainage from the eastern portion of the Rocky Mountain region south of St. Mary River and north of Helena, Mont. An examination of this stream was made by H. M. Wilson in 1890–91, the results being printed in the Twelfth Annual Report of the United States Geological Survey, part 2, pages 120–133. The stream carries a considerable amount of water. There are known to be several reservoir sites, and there is a large body of irrigable land, much of it in public ownership. This has been withdrawn, pending survey, by Secretary's order dated October 17, 1903.

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[a] For detailed report, see pp. 307–313.

A reconnaissance was made in the fall of 1903 by C. H. Fitch, who examined the country to be irrigated and the localities where Sun River may be diverted. In November, 1903, C. T. Prall established a gaging station on Sun River at the mouth of the canyon, where systematic measurements of the river were begun.

About July 1, 1904, a party for the investigation of this project was organized, with S. B. Robbins, engineer, in charge. Work was begun by running a line of levels from Sun River, near reservoir No. 1, to what is known as Freezeout basin, and in making a plane-table survey of the latter to determine the practicability of utilizing it as a storage reservoir. In October, 1903, about 300,000 acres were withdrawn from entry, and on September 15, 1904, request was made for the withdrawal of about 250,000 acres additional, making a total of about 550,000 acres withdrawn under this project.

CROW RESERVATION PROJECT.[a]

This refers to the irrigation, in pursuance of the act of Congress approved April 27, 1904, of certain bodies of land lying along the Yellowstone and Bighorn rivers in the State of Montana. Most of the lands to be reclaimed lie in the ceded portion of the Crow Indian Reservation.

Under this act the Crow Indians ceded to the United States a strip of land in the northern part of their reservation, subject to certain conditions, which included the payment of $1,150,000 and the surveying of the lands. The Indians on the ceded strip are to have a reasonable time within which to elect whether they will remain there or remove to the diminished reservation and have their improvements appraised and sold. After the completion of allotments to Indians the residue of the ceded lands are to be subject to withdrawal and disposition under the reclamation act. It is provided, however, that if the lands withdrawn under the reclamation act are not disposed of within five years after the passage of the act of April 27, 1904, then all of the lands are to be disposed of as other lands provided for in the act.

The price of these lands is to be $4 per acre when entered under the homestead laws, in addition to the cost of reclamation. Lands under the reclamation act are not to be entered or settled upon until sixty days after the President's proclamation opening the general lands to settlers.

Soon after the passage of the above-mentioned act Goyne Drummond made a preliminary reconnaissance and reported that on the Bighorn River, from the Fort Custer Military Reservation to the mouth of the river, are about 35,000 acres of fine land and that there are also about 10,000 acres inside the Fort Custer Military Reservation but outside of the ceded strip. All of this land could be covered by a canal diverting water from Bighorn River. Another canal from the Bighorn, taking water from the mouth of the canyon, would cover approximately 17,000 acres on the ceded strip and 20,000 acres on the reserve, this land lying on the high bench west of the river and adjoining the lower tract previously mentioned.

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[a] For detailed report, see pp. 326–330.

There is a possibility of the high-line canal crossing the divide between the Bighorn and Yellowstone rivers. By this perhaps 50,000 additional acres of land could be covered that could not be profitably irrigated from the Yellowstone. A survey is necessary to determine the feasibility of crossing the divide with the high-line canal.

A tract of about 1,000 acres lies on the east side of the Bighorn near its mouth. A survey will be necessary to determine whether or not this area is susceptible of irrigation.

If the above estimates are correct, there would be about 130,000 acres of land to be watered from Bighorn River under the Crow Reservation project.

On the Yellowstone is a fine body of irrigable land, comprising about 40,000 acres, extending from Huntley to the mouth of Bighorn River. This land can be irrigated at a low cost per acre. In addition to the large tracts already mentioned there are approximately 30,000 acres lower down the Yellowstone, extending from Myers to Forsyth. Of this land about half is on the reservation, the rest being mostly in private ownership. Owing to the favorable nature of the reconnaissance report and the provision in the law requiring the development and sale of the lands within five years, it was decided to make an early examination, with the idea of at once starting the necessary field work. In May, 1904, A. P. Davis and C. H. Fitch made a preliminary examination of the tracts reported on by Mr. Drummond and ordered that the preliminary survey and general investigations be at once undertaken under the direction of R. S. Stockton. The first party was put in the field about June 1, and ran a flying line of levels to determine the feasibility of a high-line canal from the mouth of the Bighorn Canyon. Toward the last of June this work was completed, and it was decided to make a preliminary location of the high-line canal. About the middle of July a topographic party was organized and put to work on the diversion sites and special features requiring detailed topography. This party has made maps of the dam site at Bighorn Canyon, the diversion point at Two Leggin Creek, the Toluca divide, and has started the work on the Yellowstone at Huntley. In August a third party, under W. E. Swift, was outfitted and started on a preliminary canal location for the lands along the Yellowstone below Huntley. Gaging stations have been established on the Yellowstone at Billings, on the Bighorn at Fort Custer, and on Pryor Creek at Huntley. Discharge measurements have been made on these streams from time to time.

Three parties have been actively engaged on the preliminary surveys. The first party is locating a high-line canal, starting from Bighorn Canyon and covering lands west of Bighorn River. This survey has progressed as far as Two Leggin Creek and the location has been made with some care, as it is hoped that this canal can be carried through the Toluca divide to lands on the Yellowstone slope. The second party has taken detailed topography of the rough country adjacent to the diversion site above Huntley. The resulting maps will be used to make a careful study of the canal location in that vicinity. The third party has made a preliminary canal location to cover the lands below Huntley.

The opening of the reservation is being deferred until the lands have been surveyed and the engineers of the Reclamation Service have determined the irrigable lands to be withdrawn. If the lands withdrawn under the reclamation act are not disposed of within five years after the passage of the act of April 27, 1904, then they are to be disposed of as are the other lands provided for in the act. It is therefore desirable that diligence be used in pushing this project to construction. The field parties were therefore kept out until the preliminary surveys were completed.

SUMMARY OF OPERATIONS IN NEBRASKA.

NORTH PLATTE PROJECT.[a]

North Platte River rises in northern Colorado, flows northward into Wyoming nearly to the center of the State, and then turns eastward and flows southeastward into Nebraska. From the center of Wyoming it receives Sweetwater River, which passes through valleys and occasional narrow gorges, and joins the North Platte at the entrance of the narrow canyon about 50 miles above Casper, the terminus of the Elkhorn Railroad.

The North Platte River projects contemplate, first, the storing of all the surplus water of North Platte River, and the regulation of the flow of the stream to meet the requirements of irrigation, power, or domestic uses; and, second, the diversion of the regulated flow from the river at points lower down into canals for the irrigation of lands in both Nebraska and Wyoming.

With these objects in view, storage was first sought. A well-known reservoir site on the Sweetwater was investigated, but the water supply was found insufficient. A second site, found at the mouth of the Sweetwater on North Platte River, proved satisfactory. It is called the Pathfinder site.

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[a] For detailed report, see pp. 331-337.

The next step was to find irrigable land. That lying below the Pathfinder reservoir on both sides of the river from Alcova to Casper was first examined, but the cost was found to be prohibitive, and that between Casper and Douglas was next taken up. There appear to be about 20,000 acres on the south side, nearly all in private ownership, which may be reclaimed at a cost of about $35 per acre. On the north side 25,000 acres may also be reclaimed at a cost of $35 per acre. No further investigations are being made at present.

The survey of Goshen Hole showed that about 150,000 acres can be reclaimed in Nebraska and Wyoming, at a cost, however, probably exceeding $35 per acre. Its reclamation is therefore at present in abeyance.

Goshen Hole lies on the south side of the river in the extreme eastern part of the State. The land is good; it lies at an elevation of about 4,000 feet, and is mostly in public ownership.

The features of construction are an expensive dam at Guernsey, a 140-mile canal, about 6 miles of tunnels, and several storage reservoirs. No work will be done during the rest of the year except, possibly, drilling at the dam site.

PATHFINDER RESERVOIR.[a]

As stated, this reservoir is located on North Platte River at the mouth of the Sweetwater. The dam location is about 4 miles below that point in a granite canyon, 60 feet wide at the bottom, 160 feet at the top, and about 180 feet deep. The height may be made 220 feet by making the dam 250 feet long on top. The capacity exceeds 1,000,000 acre-feet. The reservoir has been mapped, preliminary estimates and drawings of the dam have been made, test pits sunk, power possibilities investigated, and the preliminary examinations practically completed. It is probable that the reservoir will hold all of the flood and surplus waters flowing into North Platte River at this point.

The survey of this reservoir site was begun on August 1 and completed about October 20, 1903. The resulting maps of the dam site are on a scale of 50 feet to 1 inch, and those of the reservoir site are on a scale of 1,000 feet to 1 inch. In all, 36 square miles have been contoured.

Diamond-drill borings for bed rock were begun at the dam site on September 1 and completed on October 20, 1903. The foundations were found to be of solid granite and at a depth of only about 10 feet below low-water mark. Estimates from the plans not yet completed indicate that the cost of the dam will approximate $1,000,000.

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[a] For detailed report, see pp. 335–336.

GOSHEN HOLE SUBPROJECT.[a]

An endeavor was made to find, along North Platte River, land to which water stored in Pathfinder reservoir could be applied; little was found in Wyoming except that in Goshen Hole, which is an area of undulating, nearly level land lying in the eastern part of the State, south of North Platte River. Its name is derived from the fact that it is partly inclosed by abrupt mesas or bench lands. The area was studied by George I. Adams, the results being given in Water-Supply Paper No. 70. Various surveys made by individuals and corporations showed that much of the irrigable land in this region could be reached by a canal from North Platte River.

The investigations by the Reclamation Service were begun on April 1, 1903, the engineer in charge making a reconnaissance and organizing a survey of canal lines. The work was continued until the end of November, when the weather prevented further operations. About 150,000 acres of good land in Goshen Hole can be irrigated. An expensive dam must be built in a narrow gorge on North Platte River at a point about 1 mile above the town of Guernsey. Its crest will be 100 feet above low water and 1,400 feet long.

The canal line on the south side of North Platte River passes for the first 30 miles through a very broken country, where construction is difficult and expensive. The canal on the north side could be taken out and the waters conducted across the North Platte by means of an inverted siphon, crossing the river about 3 miles below Fort Laramie; this line would, however, be more expensive than the south-side line.

In either case the canal will be about 140 miles long, and will cover upward of 10,000 acres of irrigable land in western Nebraska. There are several good reservoir sites in Goshen Hole, and by utilizing these the size of the canal can be reduced and the cost materially decreased.

Survey of the north-side line was continued from the point where it was proposed to construct the inverted siphon and carried to a point about 10 miles east of the Wyoming-Nebraska line, a distance sufficient to show that a large amount of land can be covered, probably more than on the south side of the river. This extension was found to be infeasible.

Twenty-six square miles of irrigable land have been mapped near the head of the canal on the north side, and 13 square miles just below the proposed siphon, both on a scale of 1,000 feet to an inch. A plane-table survey was made of 37 miles of the canal on a scale of 500 feet to 1 inch, and 54 miles were run with level and transit.

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[a] For detailed report, see pp. 334–335.

The preliminary estimates show the cost of the Goshen Hole canal and the dam at Guernsey to be about $3,000,000, making the cost per acre about $25. This estimate did not include the cost of laterals and contemplated a capacity of but 1,200 second-feet. Revised estimates were made at the suggestion of the board of consulting engineers, and $500,000 was allowed for the construction of laterals and $500,000 for increasing the capacity of the canal. The raising of the dam and the revised estimates of its cost brought the total to nearly $5,000,000. The project was deemed infeasible at this time by the board of consulting engineers, or until further investigations had been made.

INTERSTATE CANAL.[a]

An examination has been made of the lands in eastern Wyoming and western Nebraska, lying on the north side of North Platte River. This examination indicated that a considerable body of land can be irrigated in Nebraska, amounting to possibly 100,000 acres, and about 25,000 acres in eastern Wyoming.

There are in both States, in private ownership, uncompleted canals, which were designed to extend much farther and to cover much more land than is at present served by them, the completion of the work having been prevented by financial reverses and other difficulties. It is now proposed to extend these canals to cover the land as originally contemplated, but it is doubtful whether the extensions will be made, though possibly an interstate canal might be constructed by the Reclamation Service. The results of such a canal would be superior to those which could be expected from the construction of the extensions for several reasons: (1) The cost would possibly be less per acre; (2) the landowners would acquire an interest in an assured water supply from the Pathfinder reservoir, and (3) questions of priority and of use would be eliminated. It may therefore be possible to irrigate 50,000 acres in addition to the land already mentioned.

Sufficient level lines have been run on the north side to demonstrate the feasibility and practicability of constructing a canal which will serve the lands mentioned, and a topographic survey is now under way which will show the amount and kind of irrigable land under the proposed line. The head gate would be at a point about midway between Guernsey and Fort Laramie, Wyo., on North Platte River. and the canal would extend into Nebraska to the vicinity of Bridgeport. Its length would probably be 150 miles; capacity at the head,

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[a] For detailed report, see pp. 336–337.

2,000 second-feet; area possible to irrigate from it, 200,000 acres, of which about 100,000 acres are above all existing or contemplated canals or extensions. Eighty per cent of this land is in the hands of the Government and subject to the provisions of the reclamation law. About 25,000 acres are under the Whalen Falls canal, not yet completed. By agreement with the owners of this canal, right of way through the canal has been secured and it will be enlarged and extended into Nebraska.

About 60,000 acres of excellent land lie under the proposed extension of the Farmers' canal in Nebraska. Of this it is probable that private owners will wish to purchase water for 30,000 acres.

The following is a tabular statement of lands under the canal:

Lands lying under the proposed Interstate canal.

[In acres.]

	Minimum.	Probable.	Maximum.
Public lands	80,000	80,000	100,000
Private lands	20,000	50,000	80,000
Carey segregation		10,000	14,000
Total	100,000	140,000	194,000

SUMMARY OF OPERATIONS IN NEVADA.

In Nevada an examination of the opportunities for reclamation was begun in 1889 and general surveys were made in 1890. Stream gagings have been continued at intervals since that date under charge of L. H. Taylor, and the large amount of information available concerning the water resources made it possible to reach an early conclusion regarding the merits of various projects. Work was therefore begun at an early date on the plans and estimates for utilizing the waters of Truckee and Carson rivers.

TRUCKEE-CARSON PROJECT.[a]

The principal water supply for western Nevada comes from the mountains of California, near the western boundary of the State. The principal streams are Truckee, Carson, and Walker rivers. These converge toward the desert lands and disappear in sinks or lakes at altitudes of about 3,900 feet. Around these sinks are broad bodies of desert land, much of it of excellent quality when watered. A number of reservoir sites on the headwaters of Truckee and Carson rivers have been surveyed and opportunities for diverting the water have been examined. The most important point at which water may be held is in Lake Tahoe, which lies across the State boundary, being partly in California and partly in Nevada. The outlet into Truckee River is in California, and the river continues in that State for several miles. The simplest project, from an engineering standpoint, is to utilize Lake Tahoe; but owing to the legal difficulties it has not been deemed wise to begin at the upper end of the river.

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[a] For detailed report, see pp. 344–359.

The waters of Truckee River are used for the irrigation of lands in the vicinity of Reno. Below these lands the river flows through a narrow canyon and then turns to the north, its waters being lost in Pyramid and Winnemucca lakes. In this lower canyon it is proposed to build a canal, taking out the flood and excess waters of Truckee River, which would otherwise be lost in the lakes, and carrying them southeastward to a reservoir site on the lower part of Carson River. In this same reservoir the excess waters of the latter stream can also be used. From this reservoir distributing canals can be built to cover several hundred thousand acres of land near Carson Sink.

Plans and estimates made by L. H. Taylor were submitted to a board of consulting engineers, consisting of Messrs. Wisner, Davis, and Quinton, and approved by them in May, 1903. Bids were opened in July, 1903, and contracts entered into for the construction of the canal from Truckee River, the work consisting of three divisions. A contract was entered into with C. A. Warren & Co., dated September 3, 1903, to construct divisions 1 and 2 of the main canal, and on August 28, 1903, with E. B. & A. L. Stone Company, to construct division 3 of the canal.

Work on the three divisions of the Truckee canal is being pushed forward under the contracts above noted. In addition, surveys are being made of the irrigable land on a scale of 1,320 feet to the inch, with contour intervals of 5 feet. This work in Carson Sink Valley is almost finished. Surveys of the distributing, lateral, and drainage canal system are also being prosecuted, and preparations for constructing a part thereof are nearly complete. The retracing of section and township lines and reestablishment of lost and obliterated corners in the district proposed to be irrigated is almost finished. The work of setting the corners of the homestead tracts or farm units, in accordance with the plats thereof approved by the Secretary of the Interior, has been commenced.

The present condition of construction is as follows:

On the main Truckee canal, while both contractors began work within one month after signing the contracts, they made very slow progress, having a comparatively small force employed during the first four or five months, and at the end of February only about 17 per cent of the excavation on divisions 1 and 2 and 28 per cent of that on division 3 had been completed. During February, however, each contractor very largely increased his working force and made such progress that division 3 was completed on September 30, 1904, and division 2 shortly afterwards.

During the past winter and spring two engineering parties were employed making surveys for and locating the canals for distributing the water to the lands in Carson Sink Valley. In the early summer two additional parties were detailed to this work and to making surveys upon which to base plans for drainage.

It is proposed to divert water from Carson River at a point about 5 miles below the lower Carson reservoir site by means of two main canals, that on the south side of the river having a capacity of 1,500 second-feet, and that on the north side of about 400 second-feet. These canals, with their main branches, will traverse Carson Sink Valley, and constitute the main distributing system for about 200,000 acres of land.

Plans and estimates made by L. H. Taylor were submitted to a board of consulting engineers consisting of Messrs. Quinton, Sanders, and Savage, and approved by them April 15, 1904; the recommendation was approved by the Secretary on May 24, 1904. Proposals for the construction of 37 miles of the main distributing canals, with diverting dam, regulating gates, spillways, falls, weirs, and bridges, were asked for, received and opened at Reno, Nev., on July 15, 1904. Contracts for this work were awarded as follows:

Earthwork, about 1,500,000 cubic yards excavation, to Pacific Coast Construction Company, of Portland, Oreg. Contract dated September 9, 1904.

Headworks to R. C. Mattingly, of San Francisco, Cal. Contract dated September 29, 1904.

Falls, lateral head-gates, spillways, etc., to the San Francisco Construction Company, San Francisco, Cal. Contract dated September 17, 1904.

Bridges to C. W. Swain, of Ione, Cal. Contract dated August 19, 1904.

Each of these contractors, except the contractor for the bridge work, began work during the month of September, and promise to push the work with all reasonable dispatch.

Diamond drilling at the lower Carson dam site was completed in July. The examination of the soils of Carson Sink Valley was completed about August 1, 1904. The topographic survey of the irrigable land and the location of distributing and drainage canals will be completed at an early date, and proposals for the construction of a portion of these canals will be sought.

ALKALINITY OF GROUND WATERS.

Throughout the Carson Valley are numerous alkali flats and a general distribution of black and white alkali incrustants upon the surface. This material was originally distributed throughout the soil, but has accumulated in large quantities as the result of lack of drainage. The waters which fall upon the ground or flow beneath the surface dissolve the soluble alkalies and carry them along until halted in their course, when they evaporate rapidly, especially in warm weather, leaving a deposit of alkali upon the surface. This is the principal reason that in the Carson Valley there are so many alkali flats. They mark the places where drainage is poor.

The ground water under any region is the principal receptacle for all soluble substances in the ground, and in an alkaline section like Carson Valley the waters flowing beneath the surface generally contain large proportions of dissolved alkali, which may be detrimental to plant life if raised to the surface. The process of irrigation raises the ground water table, and if no drainage ditches are provided the highly charged water will finally reach the surface and probably injure the crops. Therefore it is necessary to ascertain the character of the ground water and its variations throughout a proposed irrigation area in order that the highly alkaline spots may be recognized and intelligently managed.

The work involved in the ground-water investigation was carried on in Carson Valley from May 20 to October 1, in which time the entire area which it is proposed to irrigate, covering about 200,000 acres, was visited. Wherever wells had been sunk the water was taken from them, but the larger proportion of the samples were collected from wells bored for that purpose with a hand auger. In this way data were obtained by which the alkaline constituents of the entire area were determined and a map prepared showing the variations in concentration of alkalies in the ground water.

The work was carried on by Herman Stabler and William W. Burnham, hydrographic aids, under the direction of M. O. Leighton, hydrographer in charge of investigations into quality of water.

TELEPHONE LINE.

In connection with the construction work now under way and proposed about 75 miles of telephone line is being constructed, extending for about 25 miles from Reno to the head of the Truckee canal; thence along the canal for some 31 miles to the lower Carson dam site; thence to and along the line of the main distributing canal for about 19 miles to a point near Fallon, where a construction camp will be located. The cost of this line complete will probably not exceed $12,000.

RECONNAISSANCE SURVEYS.

Reconnaissance surveys have been carried on along important streams in Nevada, largely in cooperation with the State engineer. Measurements of important streams are also being made in cooperation with him, and facts concerning the location and extent of irrigated lands and the character and extent of present water rights are being determined. Measurements of the return of seepage water entering the river below the irrigated lands in Reno Valley and studies of evaporation at Lake Tahoe and other points in the basin of Truckee and Carson rivers are also being made.

SUMMARY OF OPERATIONS IN NEW MEXICO.

In New Mexico preliminary work was begun in 1902 by W. M. Reed, district engineer, and a large number of localities have been examined. Out of the various projects suggested lower Rio Grande, Pecos, Hondo, Galinas, Sapello, and Canadian rivers were selected for preliminary surveys.

HONDO PROJECT.[a]

This project is located on Hondo River, a tributary of Pecos River, in southeastern New Mexico, about 12 miles southwest from the town of Roswell, in Chaves County. A complete survey has been made of the reservoir and inlet and outlet canals. The area and capacity of the reservoir and the quantities to be removed in the construction of the canals have been determined. Diamond-drill borings have been made at various points within the reservoir site to determine the nature of the underlying strata and to ascertain their imperviousness. Borings have also been made at points where the most important structures will be erected. A complete topographic map has been made of the reservoir site and of all the lands that would be susceptible of irrigation under this system.

The project has been examined at various times by the consulting engineers of the service, and on November 10, 1903, authority was given by the Secretary to take such further action as might be necessary. On May 2, 1904, another examination was made by A. P. Davis, supervising engineer, and George Y. Wisner, J. H. Quinton, and B. M. Hall, consulting engineers, and in June, 1904, the board of consulting engineers recommended the construction of the reservoir, and the site, which was held in private ownership, was ordered purchased.

The area to be irrigated under this project amounts to 10,000 acres, and the cost will be about $28 per acre. The land that can be most easily and economically irrigated has passed from Government ownership by patent, and the people have formed an organization similar to the one in the Salt River Valley, Arizona, for the purpose of dealing with the Government and administering the affairs of the water users. More than 10,000 acres have been offered by signers of the articles of incorporation of the water users' association, and it remains for the Government to determine the exact boundary lines of the district to be irrigated.

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[a] For detailed report, see pp. 360–368.

Proposals for the construction of the reservoir were opened at Roswell, N. Mex., on September 6, 1904.

URTON LAKE PROJECT.[a]

This project is on Pecos River, in eastern New Mexico, about 60 miles north of Roswell, in the vicinity of old Fort Sumner, the lands lying in Guadalupe and Chaves counties.

It is proposed to divert the waters of the Pecos by means of a dam and a canal about 35 miles long, the flood waters to be stored in a large natural basin or reservoir provided with an outlet tunnel and distributing canals. The irrigable lands are nearly all in public ownership and lie south of the reservoir site and on the east side of Pecos River. The land is excellent in quality, the climate is good, and it is probable that the irrigable portions will be immediately entered. The center of the irrigable tract is about 100 miles from Santa Rosa, a station on the Rock Island Railroad, and 25 miles from Kenna, a station on the Pecos Valley and Northeastern Railway, a part of the Santa Fe system. Probably 60,000 acres can be reclaimed under this project, at an estimated cost of $1,000,000.

Field work was begun in May, 1903. The inlet canal has been definitely located and test pits have been dug along its entire length. The district susceptible of irrigation has been worked over by a topographic party. At present one man is stationed near the head of the proposed inlet canal, making river gagings and daily rod readings for the purpose of determining the amount of water available for use under this project.

Borings to determine the cost and the stability of proposed structures will be made this winter, when drill men now employed on northern projects will be available for work in warmer climates.

LAS VEGAS PROJECT.[b]

This project is situated about 5 miles north of Las Vegas, on what is commonly known as the "Las Vegas grant." This grant is owned by the community of Las Vegas and is governed by a board of trustees.

It is proposed to conduct the water from both the Gallinas and Sapello rivers to a point about 5 miles north of the town of Las Vegas and here impound it by means of a dam constructed across a narrow point in an arroyo. The regular flow of these streams has been appropriated, and it is contemplated to store the flood waters coming from the high mountains to the west, which are claimed by the residents of this vicinity to be large in amount. Gaging stations have been established on both these streams to determine the amount of water available.

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[a] For detailed report, see pp. 368–369.

[b] For detailed report, see pp. 369–372.

Steps have been taken by the board of trustees looking to the transfer to the United States of such lands as will be occupied by the structures and those to be irrigated under this project.

A map of the reservoir site and of the lands susceptible of irrigation under this project has been made and the inlet and outlet canals have been surveyed. The legal matters pertaining to the transfer of lands, etc., are being investigated by the representatives of the grant.

Borings will be made soon to determine the underlying strata within the reservoir site and at the point of proposed structures. The investigations of water supply will also be continued.

RIO GRANDE PROJECT.[a]

It is proposed to store the flood waters of the Rio Grande at some point in New Mexico for the development of the open valleys along the course of the river. Surveys made in past years show that at a number of localities water may be held along the course of the stream, notably above Mesilla Valley and above El Paso.

The survey of the Engle reservoir site and of the dam site was completed in August, 1903. A survey of the irrigable lands was then begun and continued through Mesilla Valley to El Paso, Tex. Borings for the foundations at the Engle dam site were begun in October, 1903, and completed in February, 1904. Borings near Fort Selden, N. Mex., for a diverting dam have also been made and other studies of the Rio Grande conducted with reference to storage possibilities and supply of water. Consideration is being given to the international questions involved between the United States and the Republic of Mexico. The office work has been transferred to the Trust Building, El Paso, Tex., with B. M. Hall, consulting engineer, in charge, where plans and estimates have been made for a storage dam at the Engle site and for a system of canals for irrigating all the good valley land below it in New Mexico and for furnishing water to be used in the vicinity of El Paso.

The engineers of the Reclamation Service have received requests from residents and from the Chamber of Commerce of Las Cruces, N. Mex., that the Government construct a diversion dam and several miles of canal on the Rio Grande, near Penasco Rock, to deliver water to present ditches near Las Cruces. These applicants have been advised to make definite organization and submit application from the necessary area of land to guarantee the return of the cost of the project under the requirements of the reclamation act, so as to put the matter in definite form for consideration. The diversion dam is an esential part of the main reclamation project on the Rio Grande, and its construction is requested at once for the purpose of giving immediate partial relief to the inhabitants of Mesilla Valley. The flow of the Rio Grande at this point is so fluctuating in its character that sufficient water for irrigation can not be furnished any large tract without regulation in storage reservoirs; although a small tract can be provided with a supply which would permit the raising of crops and relieve temporary distress, if permanent headworks were placed in the river and connected with existing canals. At present the rock and brush dams, which are all the inhabitants can afford, are frequently washed out by floods, and can not be replaced until the river again goes dry. This frequently leads to a total loss of crops and consequent distress and actual suffering. It is to relieve this condition quickly that the work is urged upon the Reclamation Service.

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[a] For detailed report, see pp. 419–426.

LA PLATA VALLEY PROJECT.[a]

This project is located on La Plata River, in San Juan County, in northwestern New Mexico. The water supply will be obtained mainly from Animas River and its tributaries, and possibly from Los Pinos River, in Colorado. This supply will be diverted from Animas River, either by means of canals near the Colorado-New Mexico line of an aggregate length of approximately 100 miles, or by means of comparatively short tunnels through the high divide between Animas and La Plata rivers and a much shorter line of canals connecting with the end of the tunnel.

For this project it will be necessary to supplement the minimum flow in Animas River during a portion of the irrigation season by storage, both at the head of La Plata Valley and on Animas River, there being an abundance of water for this purpose during the high-water period. The development of this project contemplates the reclamation of approximately 50,000 acres of land.

A preliminary investigation of this project was made by M. C. Hinderlider from June 14 to 24, 1904. This investigation consisted of a trip over a portion of the lands to be watered and along a portion of the proposed canal line, also a collection of data concerning lands, crops, water supply, storage facilities, etc., which were included in a report to the chief engineer, dated July 12, 1904. After examining the report, the chief engineer, under date of July 21, 1904, approved the recommendations and directed that preliminary surveys be begun.

In addition to the investigations described above a reconnaissance of the drainage basin of Florida River from its headwaters nearly to the Colorado–New Mexico line was made in August for the purpose of locating storage facilities. Nothing feasible was discovered. Bishop Lakes, lying north of Durango and west of Animas River, were also investigated to determine their utility for storage purposes, but it was discovered that these sites had already been filed on and are being developed by a local corporation for power purposes.

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[a] For detailed report, see pp. 392–394.

Fifteen townships in and tributary to La Plata and Animas valleys, in New Mexico, aggregating approximately 308,736 acres, and four and one-half townships in Colorado along Animas River, aggregating approximately 80,640 acres, have been withdrawn under the first form, pending future examinations, these withdrawals having been requested under date of August 8 and 15, respectively.

Two field parties, consisting of a level and transit party on the canal line and a plane-table party on the reservoir surveys, are now in the field, under the supervision of Mr. Hinderlider, where they will complete the necessary surveys and examinations.

RECONNAISSANCE SURVEYS.

Instructions have been issued by the chief engineer for preliminary investigations and reconnaissances of other projects, to be made when time and opportunity offer. In April, 1904, the Canadian watershed was visited by Frank S. Dobson, engineering aid, a reconnaissance being made from Springer, N. Mex., to the Texas line.

SILT INVESTIGATIONS.[a]

Owing to the long-continued drought in New Mexico, the McMillan storage reservoir of the Pecos Irrigation Company, situated 15 miles north of Carlsbad, N. Mex., was nearly empty on June 1, 1904. During a visit to this reservoir in January, 1904, A. P. Davis, supervising engineer, and J. H. Quinton and W. H. Sanders, consulting engineers, recommended that should this reservoir be emptied during 1904 investigations of the silt deposit should be made by the Reclamation Service, to obtain information to be used where conditions similar to those on Pecos River exist. These investigations showed that the reservoir had been filled 42 per cent in ten years, or 4 per cent a year, and that it would soon become uselss unless remedies were applied.

SUMMARY OF OPERATIONS IN NORTH DAKOTA.

A general examination of this State was made in 1903, and as a result attention was concentrated on the possibilities of reclaiming land in extreme western parts of the State. General field studies were also made of the occurrence of lignite and of the possibilities of using this material for pumping.

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[a] For detailed report, see pp. 379–392.

FORT BUFORD PROJECT.[a]

This project is located on Yellowstone River, the canal heading on the west or left bank about 20 miles below Glendive and about 2 miles below the mouth of Thirteenmile Creek. The survey was begun in August, and field work was finished for the season on October 24, 1903.

The first line was started at Terry and continued to Glendive. It was then dropped as being impracticable and another line was started from Glendive and continued to the junction of Yellowstone and Missouri rivers. This line, known as the "high-line canal," was continued for 82 miles and covers about 66,000 acres of land in Montana and North Dakota. Topographic maps of a strip of country varying from 1,200 to 3,000 feet in width along the high-line canal were completed on a scale of 500 feet to 1 inch. A preliminary location of the canal line was plotted on these maps and detailed estimates of cost were made, showing an average cost of $30 per acre without allowance for land damages and distributing system, which would add about $4 per acre. Under the canal in Montana there are 22,722 acres of railroad land, mainly disposed of to individuals. About 30 per cent of the irrigable land in Montana is subject to the terms of the reclamation law. In North Dakota 48 per cent of the land is thus subject to entry. The total amount of land under this canal in North Dakota is 23,206 acres; in Montana, 56,981 acres; total, 80,187 acres, of which about 66,000 are considered to be irrigable.

The high-line canal was examined in the field by a board of consulting engineers, and all further investigations on it were abandoned for the present.

During May, 1904, surveys were made of what is known as the "low-line canal," heading about 20 miles below Glendive and about 2 miles below Thirteenmile Creek, the line being run with less fall per mile than the "high-line canal." The results show that the canal, 65 miles in length, will serve 66,000 acres at a cost of $31 per acre. The irrigable lands have been mapped, topography being taken on portions of the canal line on a scale of 100 feet to 1 inch; surveys for all special structures at head-gates and creek crossings have been made; and location of the center line of the canal on the ground has been completed. Borings have been made at the dam site and along the canal line and test pits put down along the line of the canal. The Lower Yellowstone Water Users' Association has been formed and a large per cent of the private lands have been subscribed.

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[a] For detailed report, see pp. 432–439.

Field work has been completed and final contract plans worked up preparatory to letting contracts this winter or early next spring.

MOUSE RIVER RECONNAISSANCE.[a]

Mouse River heads in Canada near Qu'Appelle, and flows a little south of east for about 150 miles until it reaches the one hundred and second meridian, where it turns southward into North Dakota and runs southeastward for about 90 miles to Velva. At about this point it enters the bed of the old Glacial Lake Souris and turns northeastward, gradually swinging around to the west until at the point where it reenters Canada, a few miles east of the one hundred and first meridian, it flows nearly north. Its valley is about 180 miles long in North Dakota, but the stream, measured along the channel, is at least twice that length.

Along its southward course the river runs through a flat valley, varying from one-half to 2 miles or more in width, flanked by hills 100 to 200 feet high. These hills disappear as the river enters Lake Souris and turns northward, and the valley slopes gently upward from the river. The watershed in the bend of the Mouse is approximately parallel to and about 5 miles eastward from the southerly course of the river, all the streams draining eastward into the river's northward stretch.

The country embraced in the bend is about 40 miles wide east and west, by 60 miles long north and south. This region is cut by the main line of the Great Northern Railway across its southern end, and is practically bisected by a branch line of the same road running northwest from the main line, while another branch crosses the river into the northeast corner.

During June and July, 1904, a line of levels was carried by James A. French from the Surry divide to the dam site south of Overholt. Later this line was checked for elevations, and they were found to be correct. A traverse line for canal location was brought from the dam site along the east bank of the river and over the Surry divide, a distance of 45 miles. A plane-table survey along this line was executed for 12 miles, covering sufficient ground on either side of the line. Cross sections were taken at the dam site, and a plane-table survey of the Surry divide was made; these will give sufficient data to estimate approximately the cost of dam, canal, and cut through the Surry divide. In the latter part of July this work was discontinued to permit an approximate estimate of the cost of the project to be made in order to determine whether or not more detailed surveys shall be undertaken.

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[a] For detailed report, see pp. 444–447.

LITTLE MISSOURI RECONNAISSANCE.[a]

Little Missouri River heads in Wyoming and flows through the southeast corner of Montana, the northwest corner of South Dakota, and the western part of North Dakota, finally emptying into the Missouri.

It was proposed to divert the water in South Dakota, about 20 miles south of the north boundary of that State, then to follow the river, turning to the east on one of its branches after crossing the divide, and to store the water in lake beds along this divide. The water was to be eventually distributed along Cannonball, Spring, and Chanta Peta rivers, if practicable.

A reconnaissance was made by S. B. Robbins, engineer, and later elevations were run along the divide for canal location by James A. French, with the result that the project was found impracticable.

BUFORD-TRENTON PROJECT.[b]

During the season of 1903–4 reconnaissance investigations and surveys were made to determine the feasibility of irrigating the lands along the Missouri River in North Dakota, by the use of the waters of that river, by means of pumping and the use of lignite from the extensive beds throughout this region.

The Buford-Trenton project is situated on the left bank of the Missouri River, close to the western boundary of the State, where 18,000 acres of irrigable lands can be reached at elevations above the low-water plane of the Missouri River varying from 25 to 85 feet. It is proposed to irrigate this area by means of two pumping plants.

BISMARCK PROJECT.[c]

The Bismarck project lies in the vicinity of Bismarck. It will supply 15,000 acres of irrigable land at elevations varying from 25 to 65 feet above the low-water plane of the Missouri River at that point.

It is proposed to irrigate this tract by the installation of two pumping plants. Most of the land under this project is in private ownership. In November, 1904, the Secretary of the Interior gave his preliminary approval to the Buford-Trenton and Bismarck projects, and set aside $550,000 for their construction.

SUMMARY OF OPERATIONS IN OKLAHOMA.

In this Territory crops are successfully raised without artificial application of water, and irrigation is not essential, excepting possibly in Beaver County. A general study has been made of the conditions, and surveys and examinations have been made of various suggested projects. Principal attention has been given to the opportunities for water storage west of the Wichita Mountains and in Beaver County, the work being executed by Ferdinand Bonstedt, under the charge of Gerard H. Matthes, with office at Lawton.

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[a] For detailed report, see pp. 447–450.

[b] For detailed report, see pp. 439–440.

[c] For detailed report, see pp. 442–443.

Mr. Bonstedt has surveyed various reservoir sites, as described in the Second Annual Report of the Reclamation Service, and C. N. Gould has examined the water-supply and storage facilities. Search has been continued for possible reservoir sites and for opportunities for development of the surface and underground waters.

SUMMARY OF OPERATIONS IN OREGON.

A preliminary examination was made in this State in 1902, especial attention being given to the arid public lands in the central part of the State. In the early spring of 1903 an instrumental reconnaissance was made by J. G. Camp to determine the practicability of using water from Snake River on lands in the northeastern part of the State. In March, 1903, John T. Whistler was placed in charge of the work. A further preliminary examination of projects in Baker, Malheur, Harney, and Crook counties was made in March and April, 1903. As a result of these reconnaissances certain definite projects were selected for further examination on Umatilla and Malheur rivers and in Harney County.

UMATILLA PROJECT.[a]

This project is located in the north-central part of the State near the Columbia and west of the Umatilla, a tributary of the Columbia. The area proposed to be irrigated contains about 60,000 acres of unimproved, rolling, bench lands at an elevation of from 300 to 600 feet above sea level. Most of this land is unpatented and has been withdrawn from all except homestead entries, pending surveys. Of the patented land the larger part is unimproved Northern Pacific Railway grant land.

A line of levels was run by J. G. Camp from a point on Snake River near Riparia, Wash., southward and westward, which showed that it was impracticable to divert water from Snake River onto this land, but that the flood waters of Umatilla River might be used on it by utilizing a broad, shallow reservoir site in T. 3 N., Rs. 25 and 26 E.

Further preliminary surveys were authorized in March, 1903, and examinations made of this reservoir site, together with certain others on the upper waters of the Umatilla. The summer flow of this river is now used. The winter and flood flow is still available.

Five gaging stations have been maintained during the last year on this river and its tributaries and systematic measurements carried on to determine the amount of water available.

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[a] For detailed report, see pp. 468–469.

In addition to mapping the topography of the various reservoir sites, topographic maps were made for 25 miles of feed canal and about 20 miles of distributary canal on a scale of 400 feet to 1 inch. Estimates based on these preliminary surveys indicated that it was practicable to irrigate the 60,000 acres at an expense of not more than $30 per acre. Test pits to determine the nature of the material underlying the reservoir site, embankment line, and canal line were next made, continuing to June 1, when an examination and unfavorable report on the reservoir were made by the board of consulting engineers, who recommended, however, that a search should be made in the upper waters of the Umatilla River for other sites. This work has been taken up, and continuance on the project will depend on its results.

MALHEUR PROJECT.[a]

This project contemplates the reclamation of lands of Malheur Valley from above the town of Vale to Snake River. The irrigable tracts include about 45,000 acres of good bench land and an equal amount of bottom land lying on both sides of Malheur River.

The land under this project is mostly unimproved, but the greater portion of it is patented. Most of the patented land forms portions of The Dalles and the Willamette Valley and Cascade Mountain military road grants. The bench land where cultivated is exceptionally productive. The same is true of the bottom lands where not damaged by an excess of alkali. About 5,000 acres of bench lands and 10,000 acres of bottom land are already under cultivation. The entire summer flow of the Malheur and its tributaries in this region and practically all that of the Owyhee is now appropriated for these lands under irrigation, but measurements of the Malheur for more than five years indicate that it has abundant flood water to irrigate these lands if it can be held in suitable reservoirs until needed.

Preliminary surveys were authorized and begun in June, 1903. Two reservoir sites of sufficient capacity to retain all of the flood waters of Malheur River in ordinary years were found. Several other smaller reservoirs on Bully Creek and Willow Creek, tributaries to Malheur, have been considered in connection with the reclamation of lands lying at an altitude above the reservoir sites on the main river. These sites have all been surveyed and mapped on a scale of 1,000 feet to 1 inch. More than 70 miles of canal line, with topography on a scale of 400 feet to 1 inch, and 30 miles of preliminary line, without topography, were run and mapped.

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[a] For detailed report, see pp. 463–465.

Gaging stations have been maintained during the past year on the Malheur River at Ontario, Vale, and Harper Ranch, on Bully Creek at Warm Springs, and on Willow Creek above Dell. Estimates were made in the Washington office during the winter from these preliminary surveys, from which it appears probable that most, if not all, of the land above referred to can be irrigated at a cost of about $25 an acre, exclusive of drainage and maintenance. This is on the assumptions made as to the existence of foundations for a high dam at the Harper reservoir site.

The irrigable lands have been mapped on a scale of 1,000 feet to 1 inch. Diamond-drill investigations for the foundations at dam sites were begun about the middle of July, 1904, and are now almost completed. The surveys are completed and estimates and plans for bids and construction are now being made up.

HARNEY PROJECT.[a]

The irrigable lands of this project are in Harney Valley in the east-central part of the State, north of Malheur Lake. The valley has a total area of about 700 square miles and an altitude of approximately 4,100 to 4,200 feet above sea level. In the lowest part of the valley lie two shallow lakes, Harney and Malheur. The land in this valley, except that around the northern and eastern margin, is nearly level, and considerable areas bordering the lakes are swamps. Title to these swamp lands has been transferred by the State to large cattle companies. Much of the land has also been patented through the Willamette Valley and Cascade military road grant. Considerable areas have been allotted to Indians. Much of the remaining area has been patented through desert-land entries and small Carey Act projects, etc., so that there now remain unpatented only about 70,000 acres. This land has been applied for, under the Carey Act, by the Harney Valley Improvement Company.

Silvies River flows into Harney Valley from the north, spreading out over the lowland and inundating extensive areas in the spring. This natural spring flooding is guided and extended by inexpensive levees and ditches. These spring floods are of short duration and frequently occur so early as to be of little value to the lands. During the summer very little water remains in the river. Approximately one-half of this flood water entering Harney Valley can be stored at comparatively small expense in an excellent reservoir site in Silvies Valley, about 20 miles north of Harney Valley. The other half of this flood enters Silvies River below the reservoir site, principally through Emigrant Creek. The storing of this portion of the flood water would more or less interfere with the present practice of wild flooding of low lands in the spring, and it is thought by many that the benefits to be derived from relieving certain of the lower lands from a portion of this spring flood will be almost if not quite equal to the loss to the lands lying somewhat higher and at present receiving only the waters from the higher floods.

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[a] For detailed report, see pp. 469–470.

Gaging stations have been maintained on Silvies River and at the head of Harney Valley during the past year. These show that the total run-off entering Harney Valley is about 250,000 acre-feet and that about 125,000 acre-feet are available at Silvies reservoir site. This run-off is thought to be more than that of an average year.

During the season of 1903 the reservoir site at Silvies Valley was mapped on a scale of 1,000 feet to 1 inch, and about 350 square miles of irrigable land in Harney Valley on a scale of 2,000 feet to 1 inch with 2½-foot contour intervals. During the past winter estimates of cost were made from these surveys, and, on the assumption that there is sufficient water to irrigate 40,000 acres, it appeared that it could be done at a cost of not to exceed $20 per acre.

RECONNAISSANCE SURVEYS.[a]

Preliminary examinations have been made in Baker, Wallowa, Union, Lake, and Klamath counties, and on Silver Creek, in Harney County. It has appeared desirable to continue these investigations by making a study of the use of appropriated waters and water supply available from Powder, Wallowa, Grande Ronde, Sprague, Klamath, and Lost rivers and Silver Creek.

This summer a small reconnaissance party established gaging stations in Klamath County and made stream measurements and reconnaissance surveys for feasible projects. It also continued through the central part of the State by way of Chewaucan Valley, Silver Lake, and Silver Creek, Harney County.

SUMMARY OF OPERATIONS IN SOUTH DAKOTA.

In this State attention has been given to reclamation possibilities west of Missouri River, especially to those in the vicinity of the Black Hills. Any reclamation attempted on any of the streams of this region must be based on storage of storm water and spring flow. With this in view the country around the Black Hills has been carefully investigated for storage possibilities and the north side selected as the most promising. The project here is known as the Bellefourche, the water supply being from the Bellefourche and its tributaries. Reconnaissance surveys have been taken up as opportunities offered.

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[a] For detailed report, see pp. 471–476.

BELLE FOURCHE PROJECT.

Belle Fourche River rises in the east-central portion of Wyoming and flows northeast, then east, draining the western and northern portions of the Black Hills. This project involves the reclamation of lands to the southeast of the Black Hills, in Butte and Meade counties, S. Dak., by the diversion of the waters of Belle Fourche and Redwater rivers into a large basin east of the town of Belle Fourche. This basin is to be converted into a storage reservoir by the construction of an embankment of earth, riprapped with rock, across Owl Creek.

The reservoir will be filled by a large feeder canal 6½ miles long, 40 feet wide on the bottom, and carrying 10 feet of water. Other water supply will be from Crow, Owl, Indian, Horse, and Willow creeks, which have large flood flows during limited periods.

From the reservoir, which will have sufficient capacity to impound water for all the lands to be irrigated, the water will be distributed to lands in the valley on both sides of Belle Fourche River, where between 60,000 and 100,000 acres of land may be reclaimed, the area depending on the water supply obtainable, the records of run-off not being sufficiently complete to determine the amount. These lands are tributary to the Chicago and Northwestern Railroad, which runs a few miles south of them. The land was segregated July 18, 1903. The segregation comprises 465,600 acres.

A reconnaissance of the project was made from June 22 to 25, 1903, by R. F. Walter, district engineer, and gaging stations were established on Belle Fourche and Redwater rivers by which the daily run-off is determined. Surveys were ordered in July, 1903, by C. H. Fitch, supervising engineer, and field parties outfitted who made a preliminary survey of a canal line to Owl Creek reservoir. The north outlet canal was run to Willow Creek and a high-line canal to Dry Creek reservoir No. 2. In all 115 miles of canal line were located before work had to be abandoned for the winter.

The two reservoir sites known as Dry Creek and Wilson reservoirs were mapped on a scale of 1,000 feet to the inch, with 5-foot contour intervals. A reservoir area of 5,700 acres was thus covered, and the topographic branch of the Geological Survey took up the mapping of an area of about 75 square miles on a scale of 1:45000, with 20-foot contour intervals.

Field work was resumed April 1, 1904, and a reconnaissance survey was made of the possibility of an increased water supply from Little Missouri River and the storage of water so obtained. This has been found feasible if it is needed.

On April 25, 1904, a board of consulting engineers, appointed to

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[a] For detailed report, see pp. 477–491.

report on the project, met at Bellefourche and looked over the lands, water supply, and reservoir sites, and reported thereon.

During May, 1904, the Secretary of the Interior gave his preliminary approval to the project and set aside $2,100,000 for its construction if the final report should be approved by him and if a sufficient amount of private land should be subscribed.

On June 20, 1904, a board consisting of the chief engineer, C. H. Fitch, supervising engineer, and Morris Bien, legal adviser, visited the project and assisted in the formation of the landowners into a water users' association to be known as the Belle Fourche Valley Water Users' Association.

On August 3, 1904, the engineer of soils visited the lands to be irrigated and reported on the soil and farm entries.

On September 3, 1904, the board of consulting engineers, consisting of J. H. Quinton and G. Y. Wisner, met to consider the further information obtained during the summer surveys and to take final action on the project.

The preliminary surveys and estimates for the inlet canal to feed the storage basins, and for the north outlet canal, and the survey of the proposed Dry Creek and Wilson reservoir sites were completed in 1903.

During the last summer the south-side canal, which would water lands on the south side of Belle Fourche River in the vicinity of Vale and Empire, was surveyed and mapped on a scale of 200 feet to 1 inch. The survey of the extension of the north side canal from the point left off in November, 1903, was resumed and the line extended to Elm Creek, where a large body of vacant land is located which may be brought under the project if the private land owners under the south side canal fail to subscribe for water and that canal is not built.

The mapping of the Owl Creek reservoir site has been completed on a scale of 1,000 feet to 1 inch, with 5-foot contour intervals. The Owl Creek reservoir is an extension of the Dry Creek reservoir obtained by changing the location of the dam to a point across Owl Creek just below the mouth of Dry Creek. The capacity is more than double that at the site first contemplated, while the cost will be much less than twice that of the first site.

The mapping of the Alzada reservoir site on the scale of 1,000 feet to 1 inch, with 5-foot contour intervals, has been completed and estimates have been made; also the feeder canal from Little Missouri River has been surveyed, to be used either for the diversion of this stream to the Belle Fourche or an independent project.

The irrigable lands have been mapped on a scale of 1,000 feet to 1 inch, with 5-foot contour intervals. About 200 square miles have thus been mapped on both sides of the river above the Willow Creek divide.

Detail sheets have been completed of the main diversion dam site, Owl Creek dam site, south side canal diversion dam site, and the Indian and Crow Creek crossings. These sheets are on a scale of 200 feet to 1 inch, with 2-foot contours.

Borings have been made at all dam sites and creek crossings for information as to foundations and at points from 500 to 1,000 feet apart along the canals for classification of material to be moved.

The organization of the private landowners has secured subscriptions for about one-half of the private land under the project.

The available water supply has been estimated and plans for all permanent structures have been drawn.

A reconnaissance was made in June, 1904, of the headwaters of Bellefourche River for suitable sites for further storage, but no feasible sites were found.

The classification of the irrigable lands along the creeks and river, showing the overflow and irrigable lands has been completed and the applications pending for homestead and desert entries, many of which have been abandoned, are being examined and reported on.

A contract will probably be let early in the spring of 1905.

RECONNAISSANCE SURVEYS.[a]

In addition to the Bellefourche project, a number of other projects are receiving some attention, preliminary to future reclamation. The most important of these are those for the use of the waters of Little Missouri River and of the flood waters of Rapid Creek. A careful record is being kept of the water supply. This work is being taken up mostly in conjunction with the South Dakota stream-gaging work. Preliminary investigations are also being made on Owl, Grand, White, and Cheyenne rivers. In connection with this work 15 regular gaging stations are maintained.

SUMMARY OF OPERATIONS IN UTAH.

In this State principal attention has been directed to the Utah Lake and Bear Lake projects, in accordance with the recommendations of the State commission and the requests of citizens interested. A general reconnaissance has been made of other projects and the relative merits of various schemes for reclamation have been compared.

UTAH LAKE PROJECT.[b]

Utah Lake is near the center of the State, receiving its waters from numerous streams flowing from the Wasatch Mountains on the east.

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[a] For detailed report, see pp. 492–493.

[b] For detailed report, see pp. 494–508.

The outlet is north through Jordan River, which empties into Great Salt Lake, 42 miles distant. Water for irrigation is taken from Jordan River at a point at or below where it passes through a low range of hills, the canals diverging on each side of the river and covering valley land south of Salt Lake City.

Utah Lake is in effect a large storage reservoir, catching the mountain flow and delivering it into the canals. Unfortunately, however, the lake is too large for effective use, and the losses by evaporation are far in excess of the amount put to beneficial use. An extension of irrigation in Salt Lake Valley is dependent upon the ability to reduce the losses by evaporation and to handle Utah Lake more effectively.

The lands which will probably be included in this project are all in private ownership and comprise about 70,000 acres in Tps. 1, 2, 3, and 4 S., R. 1 W., Salt Lake meridian, though other lands favorable for irrigation are located in T. 1 N., R. 1 W. The estimated cost to irrigate the arid portion of the section is $35 per acre.

Preliminary investigations were begun by the present chief engineer in the spring of 1889, and various measurements of inflowing waters, evaporation, etc., have been made at intervals during the fourteen years preceding the passage of the reclamation law. Systematic work has been done under the immediate direction of George L. Swendsen, with the advice and general supervision of D. W. Ross.

The entire bed of Utah Lake, covering 140 square miles, has been contoured at intervals of 1 foot. The eastern shore has been mapped in 5-foot contours, covering an area of 64 square miles. All the principal streams flowing into the lake have been systematically measured, both at its flood seasons and at low water. Information has also been obtained relating to adjudicated claims to water, the acreage and capacity of all canals, losses by evaporation, and other facts. This work has been done under the immediate direction of George L. Swendsen, with the advice and general supervision of D. W. Ross.

On September 24, 1903, Messrs. Ross and Swendsen went over the ground and a general plan of further operations was agreed upon. To W. P. Hardesty was assigned the work of reporting on the possibilities of extending the irrigation systems to cover arid lands. To W. E. Young was given the Jordan River investigations, with the duty of determining the alignment and obtaining other information relating to lowering the channel of the river. Caleb Tanner, with a small party, took up the examination of conditions in the lake near the head of Jordan River. The results of these investigations were reported to the chief engineer January 9, when a plan for the improvements proposed was submitted, together with an estimate of the cost.

On November 21 and 23 Messrs. Ross and Swendsen met the chairman and counsel of the Utah arid land commission and agreed to cooperate in matters bearing on problems related to the use of water, and to take up the form of the organization of landowners necessary for carrying out any plans for reclamation.

On December 31, 1903, Governor Wells, A. F. Doremus, chairman of the arid land commission, and G. L. Swendsen conferred as to the best means of getting the project before the landowners concerned, and on January 21, 1904, a mass meeting of those interested was held at East Jordan. This meeting was attended by the chief engineer, by H. N. Savage, consulting engineer, and Messrs. Ross, Taylor, and Swendsen, engineers of the Reclamation Service, the State land commission, and about 500 landowners. The results and conclusions of the investigations in connection with the Utah Lake project were discussed and a representative committee designated to perfect such an organization as would meet with the requirements of the Interior Department.

At an early meeting this committee appointed a subcommittee, consisting of E. F. Holmes, A. F. Doremus, and F. S. Richards, to prepare an outline for a plan of organization of the water users' association.

Many meetings and conferences were held by these committees during the spring of 1904, and the project was also considered at numerous meetings of the stockholders of the various canal companies. Among the important conclusions reached is the mutual agreement relating to the value of all primary rights in the existing canals. It is believed that the basis suggested by the committee is equitable.

Conferences with the owners of arid lands concerned in the project have been satisfactory, the demand for water exceeding the estimated supply.

The field work on the project was resumed in April, 1904, an effort being made to secure such additional information as would be necessary to make definite plans and estimates. Careful observations in connection with water supply have been continued.

The water supply for this project must come from Utah Lake. The plan which now appears to be most feasible is to draw the lake down to a lower level, thus reducing evaporation and increasing the available water supply. The main portion of the water supply so developed will be used in the canal systems of the Jordan Valley, though a great amount of reconstruction will be necessary to make these systems effective. It is possible to extend the canal systems so as to cover new lands, these lying principally in the western and northern portions of Salt Lake Valley and in Tooele Valley.

The field operations during the season of 1904 have included detailed examination of conditions relative to channel construction to lower the lake level and reduce the area of water surface; plane-table surveys of the parts of Jordan River and the Jordan canals involved in the project and of the sections concerned in the drainage to Utah Lake; study of all hydrographic conditions, including water supply, evaporation, and rainfall, and classification of lands under the project and their exhibition on a general map soon to be completed.

BEAR LAKE PROJECT.[a]

Bear Lake is in northeastern Utah, extending into Idaho. It receives its waters from the adjacent small catchment area and overflows northward into Bear River at a point below its headwaters. This stream rises in the Uinta Mountains, south of the lake, flows northward through Utah and the southeastern corner of Idaho, receiving, in this part of its course, some water from Bear Lake. It turns toward the south, and passes into Cache Valley, and finally flows into Great Salt Lake. There are a number of bodies of irrigable land along the river, both in Idaho and in Utah.

A reconnaissance of this lake was made in 1889, and measurements of Bear River have been made at intervals since that time. Preliminary work under the reclamation law was authorized on July 29, 1902, and a reconnaissance was made. Two large areas of public land in southeastern Idaho were provisionally withdrawn on May 8, 1903.

Systematic surveys of the possibilities of reclamation from Bear Lake were made in 1903. A party under W. P. Hardesty examined into the question of utilizing the lake for storage, and another party under T. W. Humpherys examined the possibilities of diverting the waters from Bear River to reclaim a large area in the vicinity of Bancroft, Idaho. A general reconnaissance was also made by W. E. Young and assistants to determine the possibility of irrigating an area temporarily withdrawn pending survey in Marsh Valley and in the northern part of Cache Valley. In these two areas over 200 miles of preliminary lines have been run.

The project as a whole is very large, involving the storage of 350,000 acre-feet of water in Bear Lake, and its utilization by means of long canals extending to large areas of arid land. The water is provided by diverting the upper portion of Bear River into Bear Lake and drawing down the lake itself so as to add to the available volume of storage. The results of these examinations have been used to prepare a general plan for the improvements necessary to irrigate the Marsh Valley and Bancroft areas, where about 180,000 acres have been withdrawn pending investigations.

The results of these estimates, which were submitted to the chief engineer early in January, 1904, indicated that the lands withdrawn in the Bancroft area can be supplied with water at a cost of about $16 per acre and those of Marsh Valley at a cost of $25 per acre.

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[a] For detailed report, see pp. 514–544.

It has been suggested by the arid land commission of Utah that the Bear Lake project should be extended to include the conservation and extended use of the waters of the Cache Valley streams and such other additional supplies as it may be feasible to obtain, extending the entire system into northern Utah. These suggestions were made by the commission to the chief engineer early in February, and at the same time a general outline of the scheme and of its relation to Utah was presented.

Present field operations, which were resumed May 1, 1904, under the immediate direction of W. P. Hardesty, at the point where they were discontinued in November, 1903, consist of further examination for the most suitable points of diversion from Bear River for the lands to be benefited. The choice of points for diversion is the most difficult feature connected with the Bear Lake project. The information relating to water supply is also receiving detailed attention.

Surveys have been conducted to determine the points most favorable for utilizing the water to be developed by the scheme, Cache, Weber, Boxelder, and Salt Lake counties having been examined. A reconnaissance of storage possibilities on the branches of Bear River in Cache Valley has been made.

RECONNAISSANCE SURVEYS.[a]

A general examination of conditions in Utah has been carried on by G. L. Swendsen and assistants to ascertain the possibilities of various reclamation schemes proposed and to learn the relative value of other projects. In particular a general examination has been made of the country lying east of the Wasatch Mountains and near the headwaters of Price River. A number of reservoir sites were found, but none of any considerable size or importance.

In eastern Utah, on the Uinta Indian Reservation, H. S. Reed has been making systematic measurements of river flow and a general study of the opportunities for future reclamation, in view of the possibility that these lands may be opened to settlement at an early date.

SUMMARY OF OPERATIONS IN WASHINGTON.

In this State systematic stream measurements have been made for several years on Yakima River and its tributaries, Spokane and Palouse rivers, and considerable reconnaissance work has been carried on locating reservoir sites and examining various projects. On the passage of the reclamation law this work was extended to cover the whole of the arid region of the State. A number of projects were investigated in a preliminary way. Those found worthy of further study are the Big Bend project, the Okanogan project, and the Palouse project. It has been determined to concentrate most of the field forces on the investigation of that portion of the Big Bend area which can be irrigated from Palouse River, the works here being designated the Palouse project.

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[a] For detailed report, see pp. 544–599.

A grade line has been run from Priest Rapids, on Columbia River, to determine the amount of land which can be irrigated by a gravity system from Columbia River. It has been found that this plan is probably not feasible. Sufficient land can not be irrigated to warrant, at this time, the large expenditure necessary. A thorough and systematic preliminary investigation is being made of the feasibility of undertaking a project in Yakima Valley.

BIG BEND PROJECT.[a]

This project involves the irrigation of a large body of land in eastern Washington surrounded by Columbia River on the west, by Snake River on the south, and by the high wheat lands of the Palouse region on the north and east.

The irrigable lands in 154 townships have been withdrawn from entry pending investigation. The first withdrawal was on June 24, 1903. Investigations covering the feasibility of diverting various sources of water supply have been completed, and the report, with estimates for diverting the waters of Spokane River, has been rendered.

The estimated cost of diverting sufficient water to irrigate this very large area is so great that a careful and complete classification of all irrigable lands and a study of the distribution system for irrigating them is necessary to determine whether there is sufficient land which can be irrigated to make the project feasible. Reconnaissance work is being continued with this end in view.

PALOUSE PROJECT.[b]

During the winter of 1903–4 preliminary investigations and reconnaissance were conducted to determine the feasibility of irrigating about 100,000 acres from Palouse River. It was decided that the results warranted a thorough investigation and survey to determine fully the practicability of all the features of the scheme. The irrigable lands and reservoir sites under the project were first withdrawn under the Big Bend project June 24, 1903.

Surveys are being made of the irrigable lands, and also of the reservoir sites, canal lines, and dam sites. It is believed that the surveys can be completed this field season and a complete report with estimates of the cost of construction submitted during the winter 1904–5 in time for beginning construction in the spring if the project is found to be feasible. Active investigation was begun May 1, 1904.

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[a] For further data, see p. 609.

[b] For detailed report, see pp. 600–606.

OKANOGAN PROJECT.[a]

The irrigable lands included within the Okanogan project are on the west side of Okanogan River, in the northern part of the State, between the Canadian boundary and Columbia River. Their altitude is about 1,200 feet. Irrigation has been begun in a small way, and the land has been found to be of excellent quality for fruit and ordinary farm products. Water is obtained from Salmon Creek, a tributary of Okanogan River. The summer flow is not sufficient for the reclamation of any considerable area and storage must be provided. There are a number of depressions or coulees containing small lakes, which it is expected to utilize for this purpose.

Requests were made by the citizens of Okanogan County for examination into the feasibility of undertaking the irrigation of these lands. A reconnaissance was made by T. A. Noble in April, 1903, with favorable results, and field work was begun on May 27, 1903, and continued until November 15, 1903. Two dam sites and reservoir sites were surveyed, test pits were dug, about 11,000 acres of irrigable land were mapped on a scale of 1,000 feet to 1 inch, one outlet canal was surveyed, and various other matters were investigated. Lands were withdrawn from entry pending survey, by orders of the Secretary dated April 20 and 25, June 2, August 20, and September 8, 1903. During the following winter all notes, maps, etc., were completed and the irrigable lands classified. During the last season two additional canal lines and two additional reservoir sites were surveyed.

RECONNAISANCE SURVEYS.[b]

In view of requests and petitions submitted to the Secretary of the Interior by those interested, a thorough reconnaissance of the water supply, the amount of water appropriated, the amount of unirrigated land available, and other problems affecting the feasibility of an irrigation project in Yakima Valley was conducted during the past year. Work was commenced April 5 and continued during the field season.

In the fall of 1903 the Northern Pacific Railway Company submitted to the Secretary of the Interior a report by H. K. Owens on the cost and feasibility of irrigating 73,000 acres of land on the left bank of Columbia River below Priest Rapids. A preliminary reconnaissance was made of these lands and the general feasibility of the proposed plan examined. Investigations were also made to determine the feasibility of reclaiming a body of land which is annually overflowed by Kootenai River.

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[a] For detailed report, see pp. 606–609. [b] For detailed report, see pp. 611–625.

SUMMARY OF OPERATIONS IN WYOMING.

SHOSHONE (CODY) PROJECT.[a]

The Shoshone project contemplates the utilization of a portion of the surplus water of Shoshone River for the reclamation of land in the northern part of Bighorn County, Wyo.

Shoshone River receives its water from the high mountains adjacent to and east of Yellowstone National Park. The North Fork rises near the eastern boundary of the park, a few of its tributaries having their sources within its limits. For the first few miles of its course it flows southward, then eastward for about 45 miles to its junction with South Fork, which comes from the southwest and is of about the same length as North Fork, but discharges a smaller quantity of water. Just below the junction of its two forks Shoshone River enters a canyon 3½ miles in length. For a distance of one-half mile from the upper end this canyon is through solid granite. The narrowest place is 65 feet wide at the bottom, and 200 feet wide 250 feet above the bottom.

After leaving the canyon Shoshone River flows northeastward through a generally rolling country to its junction with Bighorn River, near the north boundary of Wyoming. From the mouth of the canyon to a point some 60 miles down the river areas of bench lands lie on both sides of the river.

The drainage basin of Shoshone River above the canyon contains approximately 1,250 square miles, nearly all of it being within the Yellowstone Forest Reserve.

A comparatively small portion of this water has been utilized. Water to irrigate small areas has been taken out of North Fork above the canyon. A canal for irrigating about 14,000 acres in the vicinity of Cody has been constructed under the provisions of the Carey Act and obtains it water supply from South Fork. Water rights under the same law have been obtained for reclaiming about 20,000 acres a few miles above the mouth of Shoshone River.

About 60,000 acres of land on the north side of the river, in the vicinity of Cody, had been segregated by the State of Wyoming under the provisions of the Carey Act. On May 29, 1899, Col. W. F. Cody and Mr. Nate Salisbury acquired from the State a right to appropriate some of the waters of Shoshone River for the reclamation of this land, but owing to the magnitude of the enterprise they were unable to raise sufficient capital to undertake the construction.

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[a] For further data concerning this project, see pp. 626-631.

On January 26, 1903, Governor Richards, in a letter to the Director, stated:

> I am authorized by the State board of land commissioners, who have in charge all lands segregated for irrigation purposes under the Carey Act, to say to you that if the General Government will take over and accept for the purpose of reclamation a tract of land in Bighorn County, lying on the north side of the Shoshone River, commonly known as the "Cody and Salisbury tract," the commissioners will be glad to relinquish this land to the United States.

On April 20, 1903, preliminary investigations were authorized by the chief engineer. Field work for these investigations, under the direction of Jeremiah Ahern, was begun in May and completed in November following.

Surveys previously made by private parties indicated the feasibility of several alternate projects. Therefore, in order that the relative merits of all alternate projects might be thoroughly studied, it was decided to make a topographic survey of all of the irrigable land and all of feasible conduit lines in the canyon.

The irrigable land and the reservoir site were mapped on a scale of 1,000 feet to 1 inch, with contour intervals of 10 feet, and the canyon was mapped on a scale of 100 feet to 1 inch, with contour intervals of 5 feet. The dam site was mapped on a scale of 50 feet to the inch, with contour intervals of 5 feet. About 200 square miles were mapped. During the winter months following, the location of a conduit in the canyon and of canals covering the largest area of land that could be feasibly irrigated was projected on the topographic sheets and plans for a dam and headworks at the head of the canyon were made. The preliminary estimates show that the construction of a high-line canal was feasible, the cost of the entire work proposed being less than $2,250,000.

The preliminary plans were passed upon by a board of engineers, and on February 10, 1904, the Secretary of the Interior set aside $2,250,000 of the reclamation fund for the construction of the project, "provided that satisfactory rights to land and water be secured, and provided that further consideration of details on the ground, by consulting engineers, results in favorable reports."

On February 13, 1904, Col. W. F. Cody, as the surviving partner of Cody & Salisbury, transferred the right of Cody & Salisbury to appropriate water from the Shoshone River to the Secretary of the Interior.

On March 5, 1904, an application for a permit to construct a reservoir and to store 159,500 acre-feet of the water of Shoshone River was filed in the office of the State engineer of Wyoming. On March 28 an enlargement application of the Cody & Salisbury permit, covering land aditional to the lands proposed to be reclaimed by Cody

& Salisbury, was filed in the same office. Both applications were filed for and on behalf of the United States.

The canal lines as located cover 103,000 acres of land, of which 93,000 are irrigable. By extending the main canal through the "badlands" below Garland it is estimated that 30,000 to 40,000 acres additional in vicinity of Frannie, Wyo., may be reclaimed. There are also several thousand acres of irrigable land in the drainage basin of Clark Fork that may be reclaimed. The total area reclaimed probably will exceed 150,000 acres. This land is at an elevation varying between 4,000 and 5,000 feet above sea level. Power for pumping water to land above the canal may be generated at several places.

All of the irrigable land under the project has been segregated.

In the last summer H. N. Savage and W. H. Sanders, consulting engineers, examined the preliminary plans on the ground, suggested some changes in the design of the dam, and recommended that construction be begun at an early date if borings at the dam site showed that the foundation was satisfactory. A wagon road is now being constructed into the canyon, over which to transport material to the tunnels and dam site. Work on the construction of a telephone line from Cody to the dam site has commenced. The main canal and tunnels are being staked on the ground and a topographic survey of additional lands is under way. Designs have been made for an impounding dam of increased height. Borings at the dam site are in progress, and the location of canal and tunnel lines, and the topographic surveys of irrigable land are being continued.

DE SMET PROJECT.

Lake De Smet is a natural basin situated in Johnson County, Wyo., east of the Bighorn Mountains. It has no visible outlet and seems to be maintained by inflow from a small catchment area. It is proposed to increase its inflow by diversion of flood and unappropriated waters of Piney Creek through a canal about 4 miles in length. Water thus stored in Lake De Smet may be taken out by canals heading at either end of the lake. The lands to be reclaimed consist of 3,000 acres along Clear Creek, in the vicinity of Clearmont, and an area, not determined, along Prairiedog Creek, east of Sheridan, or all of the stored water may be used in reclaiming land along the lower stretches of Clear Creek and along Powder River.

Preliminary surveys of this project were authorized in July, 1902. Field work was commenced by Jeremiah Ahern during that month and carried on until the following November. During the winter months following, plans and estimates of the probable cost of the project were made. The surveys resulted in topographic maps of the site, of canal lines 4 miles long, on a scale of 1,000 feet to 1 inch, with contour intervals of 10 feet, and of the irrigable land along Clear Creek, on a scale of 2,000 feet to 1 inch, with contour intervals of 10 feet. Continuance of this project is dependent upon the results of stream measurements now in progress to ascertain the quantity of water available for storage and the feasibility of canal and tunnels to conduct the waters to lands east of Sheridan.

WIND RIVER OR SHOSHONE INDIAN RESERVATION.[a]

A reconnaissance of upper Bighorn River, and of Wind River, its most important tributary, and its branches, was made by Goyne Drummond during the field season of 1904. Wind River heads in the Wind River Range in west-central Wyoming, and carries considerable water, flowing across the Wind River or Shoshone Indian Reservation, where a large amount of irrigable land is located.

POWER DEVELOPMENT AND PUMPING.

Power development is contemplated in connection with many projects. The power would usually be developed at the outlet from storage reservoirs, at diversion dams, or at drops in main canals, and transmitted electrically to pumping areas, where it could be utilized for supplying water for additional irrigation, sometimes by pumping from wells, sometimes from streams or low-line canals to high-line canals or storage reservoirs for distribution to lands difficult to supply by gravity systems, and sometimes by pumping return or seepage water for the purpose of draining lands liable to be flooded or for the purpose of returning the seepage water to lands to be irrigated.

Some projects are under investigation which depend wholly on pumping the water for irrigation. One class of these projects contemplates developing power wherever natural water-power sites can be found in the vicinity of the proposed project, and utilizing the power to pump irrigating water to lands too high to be economically reached by gravity systems of canals. Another class contemplates installing steam-power plants where cheap fuel, in the form of coal or oil, can be found, and pumping water from large systems of wells sunk in areas where the underground supply of water is abundant and reliable, or from storage reservoirs too low to supply lands by gravity systems. The power and pumping plants can sometimes be combined, but often the power will have to be electrically transmitted for considerable distances.

Temporary power plants for furnishing power cheaply for the work of construction can often be erected during or prior to construction of the permanent works, thus effecting an appreciable saving in the first cost of the later.

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[a] For detailed report, see pp. 631–634.

The study of the power development and pumping features of several of the projects is under the direction of H. A. Storrs, electrical engineer, Denver, Colo. His work consists in investigating the power and pumping possibilities and in designing and estimating costs of power plants, transmission systems, wells and pumping plants, fuel supplies, etc.

The estimates of the engineers in charge of the various projects cover generally the expenditures relating to electrical work, but, in addition, a portion of the salaries and expenses of the electrical engineer and his assistants may be properly chargeable to the various projects on which electrical work is being done, the amount of which can not be definitely determined in advance.

The principal power and pumping possibilities thus far investigated are briefly outlined below.

Arizona.—In connection with the Salt River project designs have been worked out for a permanent power plant at the Tonto dam, when the dam is completed, for generating about 3,000 kilowatts, to be transmitted electrically to Salt River Valley, to be used for pumping irrigating water from artesian wells. Power will be obtained by utilizing water diverted from Salt River above the reservoir and delivered to the power plant through a power canal located above the water line of the reservoir when full, and also water drawn directly from the reservoir. All the water used will be utilized for irrigating purposes.

The power canal is now under construction and will, as soon as finished, supply water to a temporary power plant designed to furnish electric power for operating the cement mill and supplying power for the construction of the Tonto dam. The machinery for this temporary power plant has been purchased and is being delivered. In addition, various materials and tools have been purchased to meet exigencies, at an aggregate cost of about $21,000.

A systematic examination will soon be made of the pumping plants now being operated by irrigation companies in Salt River Valley, in order to determine the efficiencies of the plants, their cost of operation, etc.

California.—Data have been obtained and some preliminary plans and estimates worked out covering power and pumping possibilities in connection with the Owens Valley, Yuma, and King River projects. On the Owens Valley and King River projects it has been proposed that power be developed at the most feasible water-power sites to be found in the mountains adjacent to these projects, this power to be transmitted electrically and applied to the pumping of underground or seepage water. On the Yuma project alternative pumping propositions have been studied, one plan contemplating steam power and pumping plants for raising water from the river for irrigating mesa lands, and another only looking to a small amount of pumping of irrigation and return water for irrigating bottom lands, in connection with the gravity system of canals, and involving a diversion weir on Colorado River.

Colorado.—In connection with the Uncompahgre Valley project, designs and estimates have been worked out covering a temporary power plant to be built on Gunnison River, near the proposed intake of the tunnel, and designed to furnish electrical power for construction work at the several tunnel headings. A steam-electrical power plant for this purpose may be located at the delivery end of the tunnel adjacent to the Denver and Rio Grande Railroad. At this point a permanent power plant may be built after the tunnel is completed, there being a large fall available. Estimates and plans of the above plants are being developed.

Idaho.—The Minidoka project contemplates the erection of a power plant, electrical transmission-line, and pumping plants for supplying water to about one-half of the area of irrigable lands included in the project, which are at too high an elevation to be reached by a gravity system. Preliminary plans, estimates, and data have been submitted for the consideration of the electrical engineer, who has visited and studied the ground in company with Mr. Ross, engineer in charge of the project, and has suggested the line of subsequent investigations to determine the local conditions and arrangement most suitable for the system.

Nebraska.—No permanent power plant has been contemplated in connection with the North Platte project, but the possibility of a temporary power plant, located about 1 mile below the dam site, has been considered. Some preliminary surveys and estimates have been made, and the ground and local conditions favoring such a plan have been studied. Detailed plans and estimates are being worked out for the building of the temporary plant indicated above, designed to furnish 300 or 400 horsepower for use on the construction of the Pathfinder dam and tunnels.

Nevada.—Contemplated power development of the Truckee-Carson project is confined to Carson River and the canals adjacent thereto. Preliminary plans and estimates have been worked out for a power plant to be built at a point on the main canal about 2 miles south of Leetville and 5 miles below the diversion dam, at the point where the configuration of the country affords a drop of about 26 feet in the grade of the canal. A contour map of the locality and other data having been submitted to the electrical engineer, the ground was examined and discussed by him with other engineers for determining the local conditions and the results to be secured. Detailed plans for the power house, including the permanent structures required for by-passing the water when needed for irrigation purposes and not needed for developing power, are being prepared.

New Mexico.—Consideration of the feasibility of pumping water from wells has been directed to two points on the Rio Grande, one in the vicinity of Albuquerque, the other in the vicinity of Mesilla.

Some preliminary estimates have been made of the probable cost of using small steam plants, but the conclusions arrived at, while not final, do not seem favorable to this method. Investigations as to available fuel supplies and the extent of underground waters are now in hand for determining the probable cost of larger pumping systems involving steam electric-generating stations, distributing power to large plants placed at the most suitable locations for obtaining a reliable supply of water from the gravel beds underlying the river bottoms, especially in the vicinity of Albuquerque.

North Dakota.—Field reconnaissances for determining the location, extent, and character of the lignite deposits of North Dakota were made during the summers of 1902 and 1903, chiefly by or under the direction of F. A. Wilder, with a view to utilizing lignite as fuel in pumping water from the Missouri River for irrigating the terraces along that stream. The reports furnish the basis of the field work begun August 17, 1904, by P. M. Churchill under direction of the electrical engineer.

Field work to determine approximately the area and elevation of the several terraces to which it is thought water may be pumped has been carried on by Mr. Churchill at several points on Missouri River between Buford and Bismarck. The various methods now in use for burning lignite, and designs of boilers, stokers, etc., which have been and are being used for this purpose, are being investigated by the electrical engineer in order to determine how this peculiar fuel can be satisfactorily utilized in the proposed pumping plants.

South Dakota.—Data have been accumulated for determining the feasibility of installing a temporary power plant to supply power for use in the construction of the Bellefourche project. The possibility of a small permanent development of power at the point on the river where a crossing must be provided for the water to be used for irrigating lands on the right bank has been suggested, but no definite data have been submitted. Plans and estimates are being made for a temporary power plant designed to supply electric power for operating pumps and other machinery for a building to be located between the main canal and the river about 8 miles below the diversion dam.

Utah.—Only a preliminary examination of the power features of the Utah Lake project has thus far been undertaken. An investigation has been made of the feasibility of utilizing electric power for operating dredges and for excavating the larger and deeper canal proposed for taking water out of Utah Lake, and of the practicability of securing and using the machinery now installed on Jordan River for this purpose, provided it should come into the possession of the Reclamation Service as a result of the proposed lowering of the grade of the canal at the Jordan Narrows.

The general plans for development of power in connection with the Bear Lake project have been submitted to the electrical engineer who has discussed them with the engineer in charge. The power development possibilities have been shown to be very great and the use of power for pumping return or seepage water has been suggested as a future necessity.

Washington.—Priest Rapids, on Columbia River, has been suggested as a possible site for a power and pumping plant for supplying irrigating water to lands situated 200 to 400 feet above the river. General data and preliminary estimates have been submitted to and considered by the electrical engineer and designs and estimates of cost are being worked out.

Wyoming.—The power-development possibilities on the Shoshone project have been but little studied thus far, but the maps recently submitted to the electrical engineer indicate that permanent power plants may be located at several points on the main canals and that temporary power development for furnishing power on the construction of the permanent works is possible at reasonable cost. The erection of the plant is awaiting the approval of the board of engineers, an estimate having been worked out to show the probable saving in cost of dam, tunnels, etc., to be effected.

INSTRUCTIONS TO ENGINEERS REGARDING POWER DEVELOPMENT AND PUMPING.

On February 6, 1904, the following circular letter was sent to all consulting, supervising, and district engineers:

> It is desired that problems involving power and pumping possibilities shall be brought to the attention of the electrical engineer as early as possible. It is not possible for him to take the initiative in these matters, but data on which to base designs and estimates of cost of power systems should be furnished him as soon as they become available.
>
> The feasibility of a project may depend upon the possibilities regarding power development and use, and as much time should be allowed for studying this phase of the undertaking as for the investigation of other engineering questions. If this information is withheld until all the plans for the irrigation system have been worked out it may often happen that insufficient time will remain in which to make a comprehensive study of the design. Moreover, some data may be lacking or some modification of the approved plans of dam, canals, etc., may be required in order to secure the best design of power plant, thereby delaying the execution of the project.
>
> In view of the foregoing the following general suggestions are made:
>
> Whenever the investigation of a new project has proceeded far enough to warrant a visit and examination by the consulting engineers their report regard-

ing the project shall state whether or not any power development is contemplated. In case such development is contemplated the report shall, if possible, state briefly the amount and probable use of the power to be developed, and shall also state when, in the opinion of the consulting engineers, the electrical engineer should receive from the engineer of the project such preliminary data as will enable him to study the situation sufficiently to decide what special additional information is wanted by him in working out the designs, plans, and estimates of the power system, or when, in their opinion, the electrical engineer should visit the project and consult with the local engineer regarding power possibilities.

On May 18, 1904, the following circular on this subject was sent to the various consulting, supervising, and district engineers:

Whenever in the course of reconnaissance suitable sites for power plants are discovered these should be examined and recommended for segregation if it is probable that they will be used for pumping water for irrigation. Such plants, if built, would be irrigation works, and the sites should be withdrawn if there is any reasonable prospect for their use by the Reclamation Service. They may be considered in the same light as possible reservoir sites.

It is entirely proper to ask for the withdrawal of lands appropriate for power plants under the first form of withdrawal provided for in section 3 of the reclamation act.

In case the land is unsurveyed the description should be such that it can be identified on the maps of the State issued by the General Land Office. If possible, the probable township in which the lands will lie when surveyed should be indicated.

LAND CLASSIFICATION.

Arizona.—The Department of Agriculture has collected a large amount of data regarding the classification of the lands under the Salt River project, and considerable information has been obtained regarding alkali and drainage. Observations will be continued looking to a more detailed knowledge of the necessities for drainage and the best methods of accomplishing this.

California.—During the winter of 1903–4 the Department of Agriculture completed the field work of the classification of lands under the Yuma project, and its notes are now in the hands of the Survey engineers. Farm-unit maps of the public lands to be irrigated have been prepared so far as possible with existing Land Office surveys. The shifting of the channels of Colorado and Gila rivers has resulted in land being cut from one side and a corresponding amount added to the other. Above the international boundary line between California and Mexico this amounts to but a transfer from one State to another, but along that portion of the Colorado which forms the international boundary this shifting of the channel actually results in a gain or loss of territory. Land Office plats do not record any of these changes, and before the canal can be thrown open for settlement a readjustment of the Land Office plats will be necessary.

A more detailed study of the drainage problem will be made, with a view to designing a system of drains.

A reconnaissance has been made in the Owens Valley to determine the feasibility of irrigating certain alkaline and swampy lands. An approximate estimate will be made of the area of land at present fertile and irrigable as well as of the damaged area which can be brought back to a fertile condition at reasonable cost.

With the development of the plans for the irrigation of these lands there will be undertaken a more detailed classification of the land, leading to the establishment of farm-unit maps. The character of the water of Owens River and its tributaries will be examined, and the seepage water will be investigated, with a view to determining how much of the large amount of return water can be used for irrigation. Should these waters prove to be of sufficient purity a large acreage can be added to the project by their utilization from gravity or pump canals. Investigations looking to the drainage of the valley will be pushed with further surveys, for a drainage system is almost as important as an irrigation system here.

Colorado.—H. Rowland Lee has prepared the farm-unit maps for the Uncompahgre Valley project, basing his classification on the very excellent work of the topographic parties. The amount of first-class land in each farm unit will probably be limited to 40 acres, and that of second- and third-class land to 60 or 80 acres. A reconnaissance has been made to determine the amount of drainage necessary for the permanent protection of the lands from seepage and alkali.

Idaho.—Farm-unit maps for the Minidoka project have been prepared by the engineers in charge of the project. The unit selected is 80 acres of land for each farm, with 40-acre farms within 1½ miles of all towns. A reconnaissance of the soils was made in July. Practically no alkali was found, but the large areas of flat land on the north side of the Snake River are underlain by a porous sand, and it is thought advisable to make a more detailed study of the conditions to determine the necessities for drainage.

Nevada.—The field work of land classification for the Truckee-Carson project has been completed and farm-unit maps have been prepared for approval. The unit selected is 80 acres of first-class land, 120 acres of second-class land, and 160 acres of third-class land. The field work of this classification was carried on by H. Rowland Lee. Some consideration has been given to the question of drainage, and tentative plans have been suggested.

New Mexico.—The work of establishing farm-unit maps for the Hondo project has been completed.

Oregon.—The reconnaissance of the Malheur project indicates the necessity of further work to determine the extent of drainage necessary for the protection of the bottom lands from seepage and alkali. This work, together with that of subdividing the land into farm units, is now being carried on.

South Dakota.—A reconnaissance of the Belle Fourche project has shown that all irrigable land is first class and that farm-unit maps can be completed in the office from topographic and canal-line maps. The unit will probably be 80 acres of first-class land, limited to 40 acres within 2 miles of all towns.

Wyoming.—An estimate of the area of irrigable land under the Sweetwater project shows that it is insufficient to warrant the construction of the project. An estimate of the value of the lands in private hands which will be flooded by the Pathfinder reservoir has been made. The lands under the North Platte project are now being classified.

CHARGES FOR IRRIGATION.

A. J. Wiley, consulting engineer, has prepared a statement showing some usual charges for irrigation by private enterprise and the equivalent permissible costs under the reclamation act.

In the preliminary work of the Reclamation Service the district engineers in the various States, after making reconnaissances of the possibilities of their districts, have made instrumental surveys of the most promising projects. The preliminary surveys having been completed, and an estimate made of the cost of the project, and the area to be reclaimed by it, a board of consulting engineers is detailed by the chief engineer to examine the project in all its features. These engineers go with the district engineer over all parts of the project, examining the land, the location of the canal lines, the mode of diverting the water, and the sufficiency of the water for the intended irrigation. Previous to the making of the estimates the district engineer has necessarily adopted certain grades and cross sections for the canal and made plans for the structures. All these are gone over in detail by the consulting board, and usually a revised estimate of cost is made. This estimate includes the probable cost of maintaining the canal for the ten-year period during which the total cost of the project, including the ten years of maintenance, is being returned to the reclamation fund.

Having determined the probable cost per acre, it remains for the consulting board to decide whether they can recommend the project as a feasible one. In order that a project may be feasible under the reclamation act, it is necessary that the land shall be promptly taken up by settlers who will meet the ten annual payments by which the cost is returned to the Government. The average cost per acre of the land irrigated by the reclamation act is considerably greater than that of land previously reclaimed by private corporations or by the

States under the Carey Act. This arises from the fact that the easy projects have already been built, and those upon which the Reclamation Service is engaged have great engineering difficulties to overcome in constructing canals over difficult country, or in providing storage reservoirs for an adequate water supply. Fortunately the provisions of the reclamation act, while providing for the absolute return of the cost of the works, are such that the ultimate cost is no greater to the settler than he has been accustomed to pay under the former more cheaply constructed systems. The cost of a canal system built by private capital, whether under the Carey Act or otherwise, is composed of two elements—the actual money expended in promotion and construction and the interest accumulated upon this money during the time of construction and settlement. The cost to the settler is increased by the profits which the project is expected to pay the promoters. Under the provisions of the reclamation act the cost to the settler is the actual cost of construction and maintenance, without interest charges or profits.

In the construction of works under the reclamation act none but the most permanent materials are employed and the maintenance charges will be light as compared with many projects built by private corporations or by the united efforts of the settlers. In the following computations it has been assumed that the terms upon which water is being sold to settlers by a number of different organizations are fairly representative of the practice in ordinary farming sections, and the computations show the equivalent amounts that the Reclamation Service could have expended per acre without increasing the cost to the settler at the end of the ten-year period.

The first case is that of one of the largest and most successful of the Carey Act developments. The system is one requiring no storage and having no difficult construction, but is well designed and very substantially built, comparing favorably in all respects with the standard set by the Reclamation Service. The cost of water rights is $25 per acre, with a minimum payment of $3 in advance, and with 6 per cent interest on deferred payments, the whole amount to be paid in ten yearly payments, during which period it is guaranteed that the maintenance charges shall not exceed 80 cents per acre for each acre irrigated. The estimate shows how much more expensive an enterprise could have been built under the reclamation act at the same cost per acre to the settler, assuming that the cost of maintenance would be 50 cents per acre per year each and charging 6 per cent interest on all payments made under either system. The first payment under the Carey Act enterprise is at the time of making the contract, and under the reclamation act it is not earlier than at the end of the first year after making the contract, so that in the first case the interest on deferred payments extends over ten years and in the second case the interest charged against the yearly payments extends over only nine years, the transaction in both cases terminating at the end of the tenth year.

Cost to settler under Carey Act enterprise at $25 first cost and 50 cents maintenance.

First cost of water right	$25.00
Interest at 6 per cent for 10 years on deferred payments	8.64
Interest allowed at 6 per cent on annual payments	6.36
Maintenance charges, 10 years, at 50 cents	5.00
Interest allowed on amount paid for maintenance	1.35
Total cost per acre at end of 10 years	46.35

Cost to settler under reclamation act.

Cost of construction and maintenance to equal $25 under Carey Act	$36.50
Interest allowed on annual payments at 6 per cent	9.85
Total cost per acre at end of 10 years	46.35

From the above it will be seen that if the cost of a project under the reclamation act, including ten years of maintenance, amounts to $36.50 per acre it imposes no greater burden upon the settler than the Carey Act enterprise, whose water rights are sold at $25 per acre.

Under some canals built by private corporations it has been customary to charge $10 per acre for water rights and from 75 cents to $1.50 per acre for annual maintenance. At the end of a ten-year period it is probable that with a well-constructed canal with permanent structures the maintenance charges distributed over all the land would be reduced to 30 cents per acre. In this case, in order to put the settler under the corporation canal on a parity with the one who was paying 30 cents per acre under the canal built by the reclamation act, it would be necessary to add to the amount paid during the ten-year period the capitalized value of the difference in yearly maintenance charges. The following comparative statement shows the amount that could be expended on the construction and ten years' maintenance by the Reclamation Service at the same cost to the settler as if he had paid $10 per acre for a water right and $1.50 per acre for maintenance:

Cost to settler under private construction at $10 first cost and $1.50 maintenance.

First cost of water right under private canal	$10.00
Interest at 6 per cent for 10 years on above	6.00
10 years' maintenance, at $1.50	15.00
9 years' interest allowed on payments for maintenance	4.05
$1.20 per year, capitalized at 6 per cent	20.00
Total	55.05

Cost to settler under reclamation act.

Cost of construction and maintenance to equal cost of water right at $10 and maintenance of $1.50	$43.35
Interest allowed on annual payments	11.70
Total cost per acre at end of 10 years	55.05

With the cost of water rights at $10 per acre and maintenance charges of $1 per acre the comparison would be as follows:

Cost to settler under private construction at $10 first cost and $1 maintenance.

First cost of water right	$10.00
Interest at 6 per cent for 10 years	6.00
10 years' maintenance, at $1	10.00
6 per cent interest allowed on payments for maintenance	2.70
70 cents per year, capitalized at 6 per cent	11.67
Total cost per acre at end of 10 years	40.37

Cost to settler under reclamation act.

Cost of construction and maintenance to equal $10 for water right and $1 per year maintenance	$31.79
Interest allowed on annual payments	8.58
Total cost per acre at end of 10 years	40.37

Where the cost of water rights is $10 per acre and the maintenance charges 75 cents per acre the comparison is as follows:

Cost to settler under private construction at $10 first cost and seventy-five cents maintenance.

First cost of water right	$10.00
Interest at 6 per cent for 10 years	6.00
10 years' maintenance, at 75 cents	7.50
6 per cent interest allowed on payments for maintenance	2.02
45 cents maintenance charges per year, capitalized at 6 per cent	7.50
Total cost at end of 10 years	33.02

Cost to settler under reclamation act.

Cost of construction and maintenance to equal $10 per acre water right and 75 cents maintenance	$26.00
Interest allowed on annual payment at 6 per cent	7.02
Total cost at end of 10 years	33.02

In some cases a charge of $1.50 per acre per year has been made without the purchase of a water right. In this case the comparison would be as follows:

Cost to settler under private construction at $1.50 rental.

10 years' rental, at $1.50	$15.00
9 years' interest allowed on payments for rental	4.05
$1.20 per year excess maintenance, capitalized at 6 per cent	20.00
Total	39.05

Cost to settler under reclamation act.

Cost of construction and maintenance to equal annual rental of $1.50 per acre	$30.75
6 per cent interest allowed on annual payments	8.30
Total cost at end of 10 years	39.05

The above estimates show that to be comparable with actual practice the following costs of construction and maintenance are permissible:

Comparative costs under private construction and under reclamation act.

Water rights.	Maintenance.	Reclamation act equivalent.
$25	$0.50	$36.50
10	1.50	43.35
10	1.00	31.79
10	.75	26.00
Free.	[a] 1.50	30.75

[a] Rental.

With the exception of the Carey Act enterprise, which has not yet completed its works, successful farming has been done under all these systems for many years, with a five months' irrigation season, producing only the ordinary farm crops.

OPERATIONS IN ARIZONA.[a]

By Louis C. Hill.

For several years past many projects have been under advisement by the United States Government for the reclamation of the arid lands of Arizona. Under the direction of Arthur P. Davis general examinations were carried on prior to September, 1901, to discover the relative value of these various projects, and as a result of these investigations detailed surveys have since been made, leading up to the early construction of the dam on Salt River below the mouth of Tonto Creek. The principal facts concerning the work in this Territory have been given by Mr. Davis in the First Annual Report of the Reclamation Service, page 75 et seq. Additional details are also given in Water-Supply and Irrigation Paper No. 73.

SALT RIVER PROJECT.

A small party under C. R. Olberg resumed investigations in October, 1902. Surveys were then begun for a power canal to divert the water of Salt River. The cadastral survey of the lands in Salt River Valley was begun in November, 1902, by Robert Muldrow, and after his transfer to Michigan in 1903 were continued by R. W. Hawley. Maps from these surveys are now published. They will be of great service in studying and locating a complete distribution system for the irrigation of the whole valley. Preliminary surveys were carried on by W. A. Farish on the Salt River above the Verde to determine the feasibility of a project for the development of power for pumping. In August, 1903, L. C. Hill was appointed engineer in charge of the Salt River project. A general map of the Salt River project is given on Pl. II.

CONTRACT WITH SALT RIVER VALLEY WATER USERS' ASSOCIATION.

In 1903 the owners of lands, mostly in small tracts, in the Salt River Valley formed themselves into an association known as "The Salt River Valley Water Users' Association," to which they pledged their lands to the amount of 200,000 acres for the return to the United States of the cost of the reservoir and auxiliary works. The articles of incorporation and the project itself were provisionally approved on March 12, 1903, and authority was granted for such preliminary work as the construction of roads, the purchase of lands required, and the preparation of contracts for the main structures. In February, 1904, the Secretary of the Interior approved a form of contract which it was proposed to enter into with the association. This form was submitted to the association and was accepted by vote on May 10, 1904. The contract reads as follows:

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[a] Investigations on lower Colorado River in Arizona and California are described on pp. 192-202.

These articles of agreement, made and entered into this 25th day of June, 1904, by and between the United States of America, acting in this behalf by Ethan A. Hitchcock, Secretary of the Interior, party of the first part, and the Salt River Valley Water Users' Association, a corporation duly organized and existing under the laws of the Territory of Arizona, party of the second part, their successors and assigns, witnesseth that:

Whereas the Salt River Valley Water Users' Association is a corporation organized and existing under the laws of the Territory of Arizona for the purpose mentioned in its articles of incorporation, a copy of which is appended to this memorandum (which is marked "Articles of incorporation referred to in the attached memorandum, and attested by the signature of the honorable the Secretary of the Interior of the United States of America and of the president of the Salt River Valley Water Users' Association, for the purpose of identification"), and are for every purpose of the interpretation, construction, and consideration of this memorandum, and of the rights of the parties hereunder, to be deemed, held, read, and considered as if fully written out or printed herein, and deemed a part hereof; and

Whereas the lands embraced within the district of lands described in section 3 of Article IV of said articles of incorporation are naturally desert and arid and incapable of proper cultivation without irrigation, and unless the waters of the Salt and Verde rivers in Arizona and their tributaries be impounded and the flow thereof otherwise regulated and controlled will, to a greater or less extent, remain unreclaimed, unfit for habitation, and uncultivated, in which condition they, or a great part thereof, are now; and

Whereas the Secretary of the Interior of the United States of America contemplates the construction of certain irrigation works under the provisions of an act of Congress entitled "An act appropriating the receipts from the sale and disposal of public lands in certain States and Territories to the construction of irrigation works for the reclamation of arid lands," approved June 17, 1902, in and across Salt River at a point about 32 miles up the course of said Salt River above the confluence of the Verde River and said Salt River, said point being near the mouth of Tonto Creek, for the purpose of there impounding the waters of said Salt River and otherwise regulating and controlling the flow of water therein, and works necessarily or conveniently incident thereto, for the use of said waters for the reclamation of arid lands along the course of said Salt River; and

Whereas the incorporators of said Salt River Valley Water Users' Association and its shareholders are, and under the provisions of its articles of incorporation must be, owners and occupants of land and the appropriators of water from said Salt River and said Verde River and their respective tributaries for the irrigation thereof, and in addition thereto such incorporators, shareholders, and constituents, and their assigns or successors, must initiate rights to the use of water from the said proposed irrigation works, to be constructed by the said Secretary of the Interior, as soon as such rights may be initiated, and thereafter complete the acquisition thereof in the manner and upon the terms and conditions to be prescribed therefor by the Secretary of the Interior, which rights shall be, and thereafter continue to be, forever appurtenant to designated lands owned by such shareholders and constituent members; and

Whereas neither the relative priority and extent of the individual appropriations of such water heretofore made by said incorporators, shareholders, and constituent members, nor the proportion of the entire waters of said water courses that has been in the aggregate appropriated by them, and which are now vested rights, have been ascertained or determined, but said incorporators, shareholders, and constituent members of said association have agreed amongst themselves, by the terms and provisions of said articles of incorporation, upon the rules and principles by and upon which the relative priority and the extent of their several appropriations and vested rights to the use of such waters shall be determined;

1. Now, therefore, if the said Secretary of the Interior shall authorize and shall cause the construction of said irrigation works, then in the determination of the relative rights of the shareholders of said association, and of their respective rights to the use of water acquired from the Government under said act of Congress, the rules and principles set out in said articles of incorporation for such determination shall be deemed the established rules and principles for that purpose.

2. That only those who are, or who may become, members of said association, under the provisions of its articles of incorporation, shall be accepted as entrymen or applicants for rights to the use of water impounded, developed, or the supply of which is or may be regulated or controlled by said proposed irrigation works.

3. That the aggregate amount of such rights to be issued shall in no event exceed the number of acres of land capable of irrigation by the total amount of water available for the purpose, being (1) the amount now appropriated by the shareholders of said association, and (2) the amount to be impounded and developed in excess of the water now appropriated. The Secretary of the Interior shall determine the number of acres so capable of such irrigation as aforesaid, his determination to be made upon due and expert consideration of all available data, and to be based upon and measured and limited by the beneficial use of water.

4. That the payments for the reservoir rights to be issued to the shareholders of said association, under the provisions of said act of Congress, shall be divided into not less than ten equal annual payments, the first whereof shall be payable at the time of the completion of said proposed reservoir, or within a reasonable time thereafter, and after due notice thereof by the Secretary of the Interior to the association. The cost of said proposed irrigation works shall be apportioned equally per acre among those acquiring such rights.

5. The said Salt River Valley Water Users' Association agrees that it will promptly collect or require prompt payment in such manner as the Secretary of the Interior may direct, and hereby guarantees the payments for that part of the cost of the irrigation works which shall be apportioned by the Secretary of the Interior to its shareholders, and promptly pay the sums collected by it to the receiver of the local land office for the district in which said lands are situate; that it will promptly employ the means provided and authorized by the said articles of incorporation for the enforcement of such collections, and will not change, alter, or amend its articles of incorporation in any manner whereby such means of collection, or the lien given to it by the shareholders to secure the payment thereof, or of any assessments contemplated or author-

ized thereby, shall be impaired, diminished, or rendered less effective, without the consent of the Secretary of the Interior.

6. The United States shall in no manner be responsible for the sums collected by said association until they have been paid into the hands of the receiver of the local land office, as provided by the law, and in accordance with such regulations as may be prescribed by the Secretary of the Interior.

7. That for the purpose of enforcing said collections, the association will adopt and enforce proper by-laws, subject to the approval of the Secretary of the Interior, and not change them so as to in anywise impair their efficiency for said purpose, and will otherwise do any and all things it is authorized and empowered to do in the premises.

8. That the association will adopt and enforce such rules and regulations as it is authorized by its articles of incorporation to adopt and enforce concerning the use of water by its shareholders and concerning the administration of the affairs of the association, to effectually carry out and promote the purposes of its organization, within the provisions of said articles of incorporation, which rules and regulations shall be subject to the approval of the Secretary of the Interior. That if the association fail to make and adopt such rules and regulations, then the Secretary of the Interior may prescribe them; but in such event it is understood that the Secretary of the Interior shall impose no rule or regulation interfering with any vested right of the shareholders of the association as defined or modified by said articles of incorporation.

9. Persons who are not now members of the association, but who may be the owners or occupants of land within the reservoir district described in section 3 of Article IV, or of added lands provided for in that section and to whom rights to the use of water, from the proposed reservoir or irrigation works, may be issued, may, at the designation of the Secretary of the Interior, become members of the association by subscribing to the stock thereof, and upon the compliance with the other conditions prescribed for such membership.

10. It is understood that in all the relations between the Government and this association and the members of the association the rights of the members of the association are to be defined and determined and enjoyed by and under the provisions of the said act of Congress and of other acts of Congress on the subject of the acquisition and enjoyment of the rights to use water, and by the laws of Arizona where not inconsistent therewith, where such rights have vested, modified, if modified at all, by the provisions of the articles of incorporation of said association.

11. Nothing contained in this memorandum, or to be implied from the fact of its execution, shall be construed, held, or deemed to be an approval by the Secretary of the Interior, nor an adoption by him, of the articles of incorporation of said association, in all their details as the form of organization of water users contemplated and authorized by section 6 of the said act of Congress of June 17, 1902; but such approval and adoption is expressly reserved until the conditions authorizing such approval and adoption prescribed in said act shall have arisen. And when the Secretary of the Interior shall make, approve, and promulgate rules and regulations for the administration of the water to be supplied from said proposed irrigation works, such rules and regulations, and such modifications thereof as the Secretary may, from time to time, approve and promulgate, shall be deemed and held to be obligatory upon this association as fully and completely, and to every intent and purpose, as if they were now made, approved, promulgated, and written out in full in this memorandum, and are to be read and construed as if so done.

In witness whereof the undersigned have hereunto subscribed their names and affixed their seals the day and year first herein written.

Ethan A. Hitchcock,
Secretary of the Interior,
For and on behalf of the United States of America, party of the first part.

[Departmental seal.]

Witness:
W. Scott Smith.

Salt River Valley Water Users' Association,
Party of the second part.
By B. A. Fowler, *President.*
Frank H. Parker, *Secretary.*

[Corporate seal.]

Witnesses:
Joseph H. Kibbey.
C. G. Williams.

The articles of incorporation of the association are given in the Second Annual Report of the Reclamation Service, pages 76-87.

POWER CANAL.

In September, 1903, final location surveys of the power canal were commenced, the work on the upper half of the canal being placed under the immediate charge of O. T. Reedy and the lower portion under A. M. Sprigg. The canal is nearly 19 miles long, and will have a capacity of 200 second-feet. The water will be carried above the reservoir to a point below the dam, and there discharged through turbine wheels under an available head of 220 feet, developing 4,400 gross horsepower. The power obtained is to be used in the construction of the dam and in pumping water for irrigation in the Salt River Valley.

The following bids were received January 7, 1904, for constructing 18 miles of irrigation canal and pressure pipes, tunnels, spillway, and gates for the conduction of about 200 cubic feet of water a second from Salt River:

Bids received for constructing canals, tunnels, etc., Salt River project.

	Dittmer & Weltbree, Pueblo, Colo.	C. F. Moore & Co., Globe, Ariz.	Lynn S. Atkinson, Colorado Springs, Colo.	P. A. Howard, Los Angeles, Cal.	Wilcox & Rose, Colton, Cal.	Edward Malley, San Francisco, Cal.	Robert Sherer & Co., Los Angeles, Cal.	Healy, Tibbitts & Co., San Francisco, Cal.	W. O. Morrison, Denver, Colo.	John Tuttle, San Francisco, Cal.	E. B. & A. L. Stone Co., Oakland, Cal.	MacArthur Bros. Co., Chicago, Ill.
Schedule 1—Excavation:												
Class 1....per cu. yd..	......	......	$0.35	$0.19	$0.27¼	......	$0.14½	$0.35	$0.48	$0.33	$0.27½	$0.28
Class 2..........do....	......	......	.50	.45	.45¼	......	.25	.59	.66	.45	.60	.45
Class 3..........do....	......	......	.75	.55	.65¼	......	.35	.80	.65	.65	.85	.50
Class 4..........do....	......	......	1.25	.99	1.47	......	.90	1.50	1.48	1.22	1.25	.75
Overhaul.. per 100 ft..	......	......	.03	.01	.02¼	......	.01	.06	.05	.01½	.02½	.01½
Concrete..per cu. yd..	......	......	10.00	7.00	8.00	......	6.00	12.90	8.50	8.10	18.00	8.75
Timber in place.per M ft..	......	......	50.00	22.00	21.00	......	17.00	45.00	14.75	27.50	22.50	21.00

Bids received for constructing canals, tunnels, etc., Salt River project—Continued.

	Dittmer & Weitbree, Pueblo, Colo.	C. F. Moore & Co., Globe, Ariz.	Lynn S. Atkinson, Colorado Springs, Colo.	P. A. Howard, Los Angeles, Cal.	Wilcox & Rose, Colton, Cal.	Edward Malley, San Francisco, Cal.	Robert Sherer & Co., Los Angeles, Cal.	Healy, Tibbitts & Co., San Francisco, Cal.	W. O. Morrison, Denver, Colo.	John Tuttle, San Francisco, Cal.	E. B. & A. L. Stone Co., Oakland, Cal.	MacArthur Bros. Co., Chicago, Ill.
Cast-iron sluice gates, etc.........per pound..	......	......	$0.10	$0.125	$0.08	......	$0.09	$0.15	$0.065	$0.10	$0.10	$0.15
Puddling.....per cu. yd..	......	......	1.75	1.50	2.15	......	3.00	2.00	1.00	2.00	3.00	1.50
Riprap........per sq. yd..	......	......	1.00	......	......	......	......	4.50	1.40	1.50	1.50	......
Schedule 2—Tunnels:												
Class 1.....per lin. ft..	$21.20	$11.25	25.00	11.50	14.35	$16.00	10.00	33.00	([a])	8.25	25.00	8.75
Lining.per cu. yd..	8.65	26.45	16.00	7.00	8.35	14.00	6.00	20.00	([a])	11.00	15.00	11.00
Class 2.....per lin. ft..	18.00	11.25	27.50	12.50	16.00	14.00	11.00	31.00	([a])	7.75	25.00	8.75
Lining.per cu. yd..	8.65	19.70	17.00	7.00	8.35	14.00	6.00	20.00	([a])	11.00	15.00	11.00
Class 3, except lining......per lin. ft..	12.00	[b]15.00	30.00	14.00	23.00	14.00	12.50	37.00	([a])	9.50	25.00	10.00

[a] See same bidder in paragraph below.

[b] "The proposal on Class 3 applies only to points of rock that may be met in running tunnels of Classes 1 and 2. It does not apply to the tunnel that may be run under the loose rock slide in the vicinity of the main dam."

The following bids were received on schedule 3, pressure pipes:

National Wood Pipe Company, Los Angeles, Cal.—Five-foot wood stave pressure pipe.

For 2,700 feet 60-inch diameter Wheeler patent continuous stave pipe, known as the Pinto Creek siphon. Staves to be furnished by the department, $4.68 per foot. For the same pipe constructed of redwood staves, furnished by us, $7.18 per foot.

For 550 feet 60-inch diameter Wheeler patent continuous stave pipe, known as the Cottonwood Canyon siphon. Staves to be furnished by the department, $6.15 per foot. For the same pipe made of redwood staves, furnished by us, $8.70 per foot.

Blow-off for 60-inch Pinto Creek pipe line, made of 24-inch Wheeler patent continuous stave pipe. Staves to be furnished by the department, $2.15 per foot. The same made of redwood staves, furnished by us, $3.20 per foot.

Blow-off for 60-inch Cottonwood Canyon pipe line, made of 24-inch Wheeler patent continuous stave pipe. Staves furnished by the department, $3 per foot. The same made of redwood staves, furnished by us, $4.05 per foot.

For flange connections of 24-inch stave pipe, $40 each.

For 24-inch beveled geared gate valve, built into 24-inch pipe lines, $305 each, including concrete gate chamber and manhole.

For 356 feet of 60-inch Wheeler patent continuous stave pipe, known as the penstock for the temporary power plant. Staves to be furnished by the department, $8.70 per foot. The same made of redwood staves, furnished by us, $11.45 per foot.

The above prices include all necessary material delivered and built in place, but do not include trenching or back-filling. All of the above pipe, and the material therefor, to be in accordance with our specifications.

Stave and binder flume.—We will build in place and furnish all material, except staves and lumber and concrete foundations. The 9-foot diameter stave and binder flume at $4.50 per foot.

We will build in place and furnish all material, except staves and lumber. The 12-foot diameter stave and binder flume at $5.75 per foot.

We will build the trestles for 12-foot diameter stave and binder flumes. The lumber to be furnished by the department, at $17 per 1,000 feet, board measure, and the concrete pedestals for trestles, at $8 per cubic yard.

The ends of the staves for the stave and binder flume to be slotted and connected with an oak tongue of similar construction to the Wheeler patent continuous stave pipe, as shown on blueprint herewith, and an extra band will be placed around each butt joint, otherwise the construction to be in accordance with your specifications and blueprints furnished us.

Lynn S. Atkinson.—Five-foot concrete pressure pipe, 3,200 feet, $15 per linear foot. Five-foot wood stave pressure pipe, 3,200 feet, $8 per linear foot for redwood or fir; $7 per foot for native. Entrance and exit gates for same, 12, at $200 each.

Twenty-four-inch blow-offs, each $300. Pipe for same, $10 per foot.

These figures based on 25-foot head. Additional bands, per pound, 12½ cents.

I desire all work in one contract.

Wilcox & Rose.—Five-foot concrete pressure pipe, 3,200 feet, $5.25 per linear foot.

	Per linear foot.
Class 1: 5-foot wood-stave pressure pipe, 3,200 feet	$4.85
Class 2: 5-foot wood-stave pressure pipe, 3,200 feet	5.15
Class 3: 5-foot wood-stave pressure pipe, 3,200 feet	5.35

Blow-offs, each, $295. Pipe for same, $2.15 per foot.

Timber trestle as per details on plans Nos. 11 and 12, $32.95 per M feet B. M.

Timber supports for 9 and 12 foot diameter wood flumes as per detail on plan No. 10, $23.75 per M feet B. M.

Wood flumes as per detail, second alternative on plan No. 11, $20.85 per M feet B. M.

Wood flumes as per detail, first alternative on plan No. 12, $19.95 per M feet B. M.

Wood flume, 9-foot diameter, per detail on plans Nos. 8 and 10, $4.35 per linear foot.

Wood flume, 12-foot diameter, as per details on plans Nos. 8 and 10, $5.65 per linear foot.

Extra rods in cement pipe, 11 cents per pound.

We reserve the right to accept all or none at our option.

Excelsior Wooden Pipe Company, San Francisco, Cal.—Five-foot wood-stave pressure pipe, 3,200 linear feet.

Proposition 1: Based on furnishing all the material and labor of erection and use of one-half inch round mild steel bands of tensile strength and spacing as per Government specifications.

	Per linear foot.
6-inch band spacing	$5.58
5½-inch band spacing	5.76
5-inch band spacing	5.95
4½-inch band spacing	6.20
4-inch band spacing	6.52
3½-inch band spacing	6.92
3-inch band spacing	7.45
2½-inch band spacing	8.19
2-inch band spacing	9.31

The above prices are for all the necessary material f. o. b. cars Phœnix, Ariz., and include the cost of erection, but do not include any haul, distribution, trenching, backfilling, gates, or special fittings, and are subject to acceptance within one month.

Proposition 2: Based on furnishing all the material and labor of erection and the use of five-eighths-inch round mild steel bands, specifications and spacing as per our usual practice as hereinafter provided.

Pressure head in feet:	Per linear foot.
0-20	$5.13
20-30	5.53
30-40	5.94
40-50	6.34

Additional price for each additional 10-foot increment in pressure up to 200 feet, 53 cents.

It is understood that the above prices are for all the necessary material f. o. b. cars Phoenix, Ariz., and include the cost of erection, but do not include any haul, distribution, trenching, back filling, gates or special fittings, and are subject to acceptance within one month from date.

Proposition 3: Based on furnishing the necessary one-half-inch round, mild steel bands, including shoes f. o. b. cars Phœnix, Ariz., exclusive of any labor as hereinafter provided.

The necessary bands for 3,200 linear feet of 60-inch diameter pipe, at 78 cents per complete band.

It is understood this price is for the material as specified f. o. b. cars Phœnix, Ariz., exclusive of any labor or haul, and is subject to acceptance by January 10, 1904.

Class 1:		
2,250 feet, except lining	per linear foot..	$12.90
Timbering, if required	per M feet..	16.00
Lining of same	per cubic yard..	12.40
Class 2:		
2,000 feet, except lining	per linear foot..	13.50
Timbering, if required	per M feet..	16.00
Lining of same	per cubic yard..	12.50
Class 3: 2,700 feet, except lining	per linear foot..	18.50

W. O. Morrison.—No excavation or back filling. For all work let.

Five-foot concrete pressure-pipe, 3,200 feet at $15.50 per linear foot.

Five-foot wood-stave pressure-pipe, imported lumber, 3,200 feet at $10.50 per linear foot.

Five-foot wood-stave pressure-pipe, native lumber, 3,200 feet at $6.50 per linear foot.

Entrance and exit gates for same, 12, "no specifications."

Blow-offs, each at $365. Pipe for same at $3 per foot.

Time required to complete work of bid No. 1 (Schedule 1), 365 working days.

Time required to complete work of bid No. 2 (Schedule 2), 270 working days.

Time required to complete work of bid No. 3 (Schedule 3), 270 working days.

(Telegram: "My bids on stave pipe covers head of 20 feet. Allow 10 per cent for each additional 5 feet.")

John Tuttle.—Five-foot concrete pressure-pipe, 3,200 feet, $7.50 per linear foot.

Five-foot wood-stave pressure-pipe, 3,200 feet, per linear foot—Class 1, $7; Class 2, $7.10; Class 3, $7.25.

Entrance and exit gates for same, 12, $200 each.

Blow-offs, each $250. Pipe for same, $3 per foot.

Extra iron bands for pressure-pipe, 8 cents a pound.

E. B. & A. L. Stone Company.—Five-foot concrete pressure pipe, 25 feet or less, 3,200 feet, $16.50 per linear foot.

Extra bands, 10 cents per pound.

Five-foot wood stave pressure pipe, 3,200 feet, per linear foot—Class 1, $8.50; Class 2, $9; Class 3, $11.

Entrance and exit gates for same, 12, $1,000 each.

Blow-offs, each, $300; pipe for same, $2 per foot.

If suitable seasoned native lumber could be furnished by the Government in the rough at the mill we would reduce our price on this item (stave pipe) by $2 per linear foot on either class upon which we have bid.

MacArthur Brothers Company.—Five-foot concrete pressure pipe, 3,200 feet, $7 per linear foot.

Five-foot wood-stave pressure pipe, 3,200 feet, $9 per linear foot.

Excavation and back filling to be paid for as excavation under its proper class.

Entrance and exit gates for same, 12, each $900.

Blow-offs, each, $250; pipe for same, per foot, $7.50.

Cast iron, per pound	$0.07
Wrought iron, per pound	.08
Riprap, 1 foot thick, per square yard	1.00
Setting culvert pipe:	
12-inch pipe, per linear foot	.25
24-inch pipe, per linear foot	.50
36-inch pipe, per linear foot	.75
Timber construction in place in semicircular flumes, per 1,000 feet B. M	30.00

Under these proposals a contract was entered into on March 18, 1904, with Robert Sherer & Company, for schedule 1 of the power canal: and with John Tuttle, on March 23, 1904, for schedule 2. Active operations began in April, 1904.

The work involves the excavation of about 600,000 cubic yards of material and the driving of nearly 9,000 feet of tunnel. The work is heavy and a great amount of cross drainage has to be handled by large culverts and conduits.

The canal will be carried under Pinto Creek by two 5-foot pressure pipes, 2,400 feet long.

Ninety per cent of the tunnels have been driven and about 60 per cent of the excavation completed (see Pl. III, *A*).

A small waterworks system was completed in the fall of 1903, which supplies about 20,000 gallons a day; no potable water is available nearer the dam than 3 miles. This system, in conjunction with the reservoir above the cement mill, furnishes some protection against fire.

TELEPHONE LINE.

On December 26, 1903, a contract was entered into with James R. Thorpe, of Denver, Colo., for the construction of a telephone line from the head of the power canal to the Arizona dam, 25 miles from Phoenix. The following is an abstract of the bids received in response to advertisement for proposals:

Bids for telephone line, Salt River project, Arizona.

Skinner & Sethman, Denver, Colo.:

Division 1.—$142 per mile, 20 miles, $2,840; 80 cents per pole, if more or less than 40 poles per mile. Exclusive of holes setting poles and instruments.

Division 2.—$160 per mile, 20 miles, $3,200; 80 cents per pole. Same items excluded.

Skinner & Sethman, Denver, Colo.—Continued.

Division 3.—$160 per mile, 17 miles, $2,720; 80 cents per pole. Same ite excluded.

Division 4.—$145 per miles, 13 miles, $1,885; 80 cents per pole. Same ems excluded.

Division 5.—Same as division 4, 16 miles, $2,320.

Seven sets instruments installed, $185.

Discount 3 per cent on entire system in one contract.

Beldon & Norris, Phœnix, Ariz.:

Division 1.—$409 per mile, furnished and erected complete. Instruments not included.

Division 2.—$409 per mile complete. Instruments not included.

Division 3.—$485 per mile complete. Instruments not included.

Division 4.—$475 per mile complete, except poles. Instruments not included.

Division 5.—$236 per mile complete, except poles. Instruments not included.

Five sets instruments installed, $100; 7 sets, $140.

Wilcox & Rose, Riverside, Cal.:

Division 1.—$136.36 per mile (40 poles), exclusive of digging holes, setting poles and instruments; $357.19 per mile (redwood poles). Add $40 for holes, $397.19 per mile complete.

Division 2.—$190 per mile (40 poles) excluding above items; $451.72 per mile complete; $370.52 per mile (redwood). Add $30 for 30 holes, at $1. Add $25 for 10 holes, at $2.50. $425.52 per mile complete.

Division 3.—$263.11 per mile (40 poles) excluding above items; $451.72 per mile complete; $658.41 per mile (redwood). Add $15 for 10 holes, at $1.50. Add $105 for 30 holes, at $3.50. $778.41 per mile complete.

Division 4.—$237.38 per mile (40 poles) excluding above items; $451.72 per mile complete; $505.60 per mile (redwood). Add $10 for 10 poles, at $1. Add $75 for 30 poles, at $2.50. $590.60 per mile complete.

Division 5.—$237.38 per miles (40 poles) excluding above items; $451.72 per mile complete.

Seven sets instruments installed, $300.

All divisions complete in one contract, $451.72 per mile.

J. R. Thorpe, Denver, Colo.:

Division 1.—$278 per mile; 18 miles, $5,000.

Division 2.—$295 per mile complete. Instruments not included.

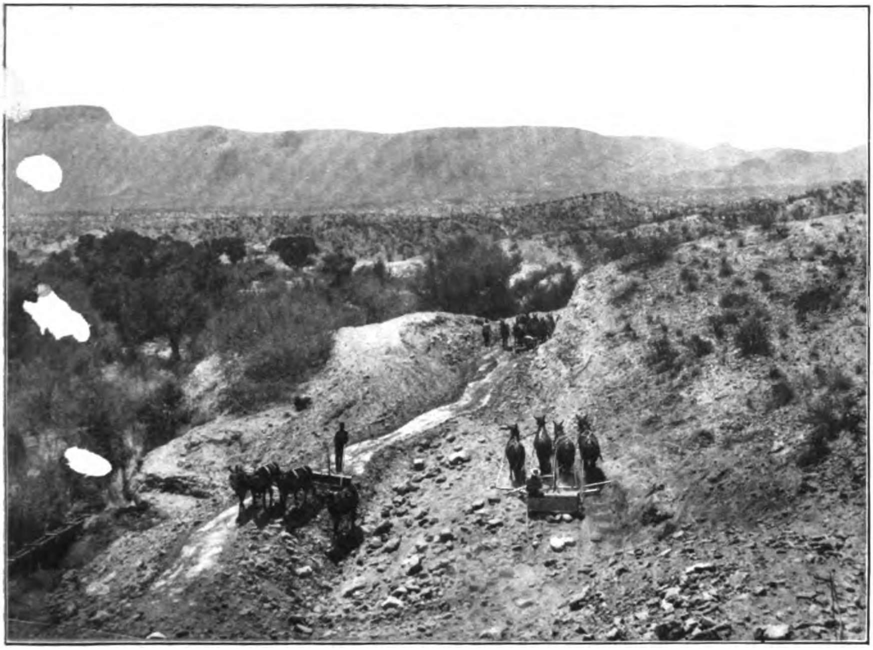
Division 3.—$447 per mile complete. Instruments not included.

Division 4.—$440 per mile complete. Instruments not included

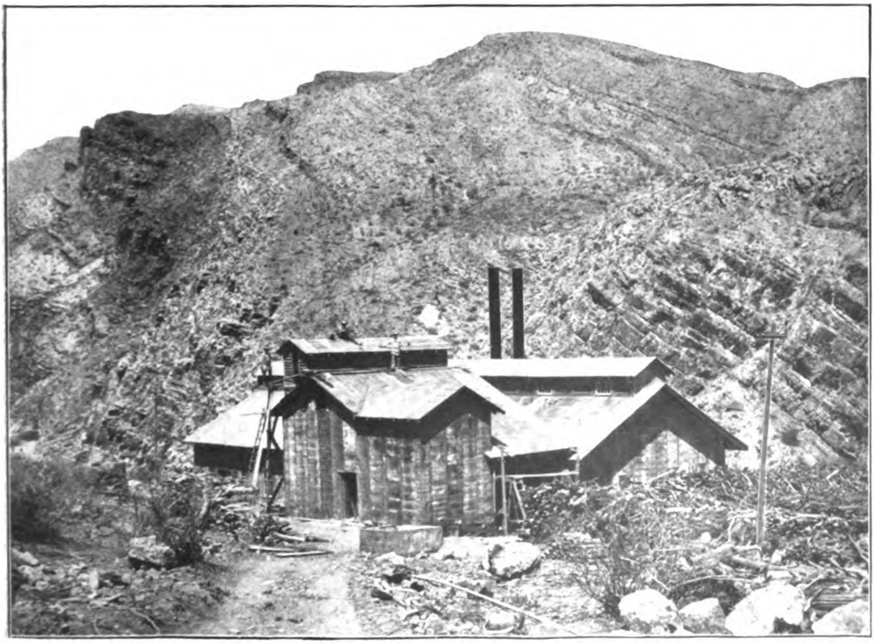
Division 5.—$350 per mile complete. Instruments not included.

Seven sets instruments $250, or $366 installed.

Part of the line has been in use since April, 1904, and work has now been begun on its extension to Phoenix, most of the material being already on the ground. The line will ultimately connect with all the power plants and, through a central station, with all the pumping plants in the valley. During the construction of the Phoenix-Roosevelt road this line was of the greatest service, and in the future operation of the whole irrigation system of the Salt River Valley will be invaluable. When completed it will be about 90 miles long, and will have cost about $35,000. It runs through a most difficult country, where much of the material had to be packed on burros, in some cases as far as 15 miles.



A. WORK ON POWER CANAL 3 MILES EAST OF LIVINGSTON, SALT RIVER PROJECT, ARIZONA.



B. TEMPORARY POWER PLANT AT ROOSEVELT, ARIZ.

ELECTRICAL MACHINERY.

The following is an abstract of the proposals received September 21, 1903, at Denver, Colo., for furnishing electrical machinery for the cement mill and the temporary power plant:

Proposals for electrical machinery.

Designation.	No. 1.—Westinghouse Electric and Manufacturing Co.			No. 2.—General Electric Co.		No. 3.—Bullock Electric Manufacturing Co.		No. 4.—Hendrie & Bolthoff Manufacturing Co.	
	Price.	Time required for shipment.	Offer Oct. 7, 1903.	Price.	Time required for shipment.	Price.	Time required for shipment.	Price.	Time required for shipment.
Class A.									
		Months.			*Months.*		*Months.*		*Months.*
One 750-kilowatt generator	$9,200.00	6½	$8,200.00	$8,241.00	7	$7,240.00	4½	$7,482.00	7
One exciter	568.00	6½	568.00	302.00	7	485.00	4½	585.30	7
One switchboard	650.00	6½	650.00	1,285.00	7	575.00	4½	507.90	7
Two rheostats	(a)	6½	....	130.00	7	(a)	....	(a)	....
Total	10,418.00	....	9,418.00	9,958.00	....	8,300.00	....	8,575.20	....
Class B.									
One 125-kilowatt generator	4,137.00	4½	3,300.00 [b] 237.00	2,795.00	5½	2,575.00	4½	3,008.40	5½
One switchboard	523.00	4½	523.00	920.00	5½	500.00	4½	436.10	5½
Two rheostats	(a)	4½	....	84.00	5½	(a)	4½	(a)	....
Total	4,660.00	....	4,061.00	3,799.00	....	3,075.00	....	3,444.50	....
Class C.									
Two 100-horsepower motors	4,302.00	4½	4,230.00	4,437.50	5	....	....	4,224.50	[c] 23
Three 50-horsepower motors[d]	(4) 4,944.00	4½	(4) 4,916.40	(4) 5,432.60	4	....	....	(3) 3,750.00	[c] 18
One 75-horsepower motor	1,783.00	4½	1,788.25	1,836.25	5	....	....	1,728.75	[c] 23
One 40-horsepower motor[d]	....	....	(d)	....	....	....	....	928.25	[c] 10
Total	11,029.00	....	10,884.65	11,706.35	....	....	....	10,631.50	....
Grand total	26,107.00	....	24,363.65	25,463.35	....	11,375.00	....	22,651.20	....
Deduction for delay				$50 per day		$10 per day		$50 per day.	
Salary for expert				$15 per day		$5 per day and expenses.		$6 per day and expenses.	

[a] Included in price of generator.
[b] Exciter.
[c] Weeks.
[d] A 50-horsepower motor is substituted for the 40-horsepower motor called for.

In accordance with these proposals contracts were entered into with the Bullock Electric Manufacturing Company, Cincinnati, Ohio, on January 8, 1904, for electric machinery, and with the Hendrie & Bolthoff Manufacturing Company, Denver, Colo., on January 6, 1904, for motors for the power plant.

The temporary installation, consisting of a 1,300-horsepower turbine and a 950-kilowatt three-phase dynamo, will be located about 37 feet above the river and will furnish power for constructing the dam and running the cement mill. Work on the foundations for this machinery is progressing, part of the machinery is at Roosevelt, and all has been delivered at Globe.

A 150-horsepower steam-power plant (Pl. III, *B*), to be used as an auxiliary, has been furnishing power for hoisting, for grinding material for fire brick, and for the machines and wood shops.

An ice plant of 2-ton capacity was completed in August and has furnished ice to the camps.

In November, 1903, work on the excavation for the foundations of the cement mill was begun. The excavation was completed in February, 1904, and early in May the foundations were finished. Wilcox & Rose began erecting the mill in July and practically finished the building in September. A large part of the machinery is now in place.

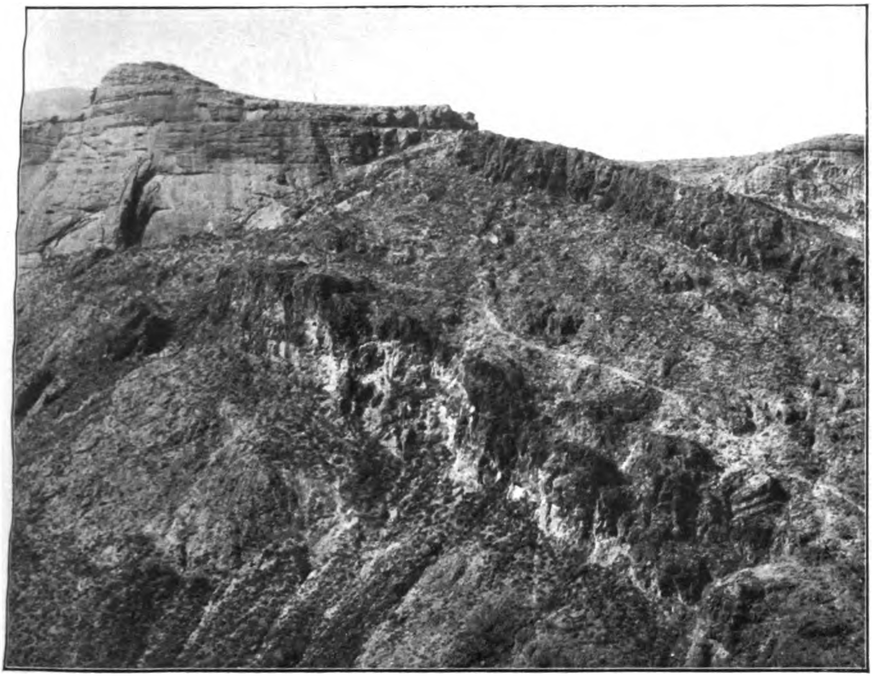
Few reservoirs have been constructed in locations where the natural conditions are so extremely favorable and transportation facilities so meager. The cement mill is built within 1,500 feet of the dam site and one corner of it is located in the limestone which forms the principal ingredient of the cement. A good quality of clay is found within a mile. Materials for making necessary brick and lime to be used in the various structures are all present in large quantities within a short distance. The rock which will enter into the construction of the dam will be excavated in part from the spillways and the rest from the hills immediately above the dam. Material for making the sand for mortar is also available within one-quarter mile of the dam site. But when it is necessary to import supplies, transportation charges are high and wagon freight expensive. Freight alone forms over 30 per cent of the cost of most articles.

ROADS.

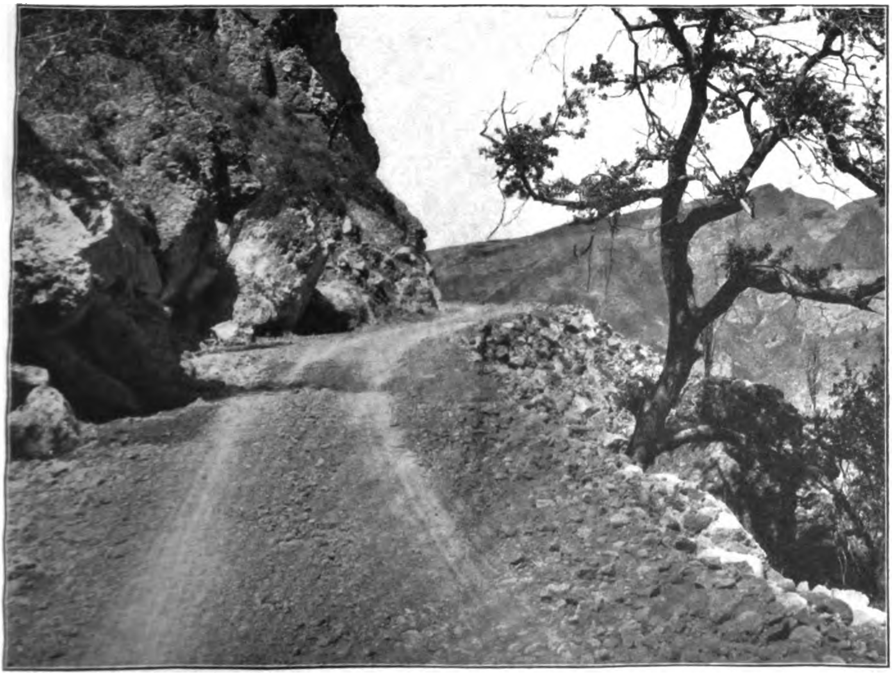
The nearest town, Globe, is 40 miles away, and it was necessary to build nearly 20 miles of road to connect it with the dam site. This work was completed in February, 1904.

Under the authority granted on March 12, 1903, a road about 3 miles long was constructed from the clay hills to a point near the proposed site of the cement mill; and another road was built leading from the Salt River to the timber in the Sierra Ancha, where lumber for use in lining tunnels and in building bridges, temporary power houses, and other works is being sawed. About 1,000,000 feet of lumber has been sawed to date, and at least as much more will be required.

In November, 1903, a small force was put to work below the dam to construct a wagon road thence to the substation near Mesa suitable for the transportation of supplies to be used in the construction of the transmission line from the power plants along the river and at the dam. Somewhat earlier, work was begun near Goldfields, on the other end of the same road. Work was discontinued on this end after some



A. EAST SIDE OF FISH CREEK HILL ALONG LOCATION OF PHOENIX WAGON ROAD, SALT RIVER PROJECT, ARIZONA.



B EAST SIDE OF FISH CREEK HILL, SHOWING COMPLETED PORTION OF PHOENIX-ROOSEVELT ROAD, SALT RIVER PROJECT, ARIZONA.

3 miles were constructed, and operations practically ceased in December on the upper end.

The people of Phoenix, Mesa, and Tempe offered to contribute largely toward this road if the United States would make it a first-class freight road. A bill was introduced into Congress, and passed, which enabled these three cities to bond themselves to aid in the construction of this road. Phoenix contributed $67,500; Tempe, $4,000, and Mesa, $3,500. In June, owing to the public spirit of a number of private citizens of Phoenix, who signed notes to protect the bank, part of this $75,000 became available and work on the road began again. By July 15, 300 men were at work; later this number was increased to 400. The road is now completed. (Pls. IV and V.)

This route is a most difficult one. The first 7 miles are through the canyon of the Salt River, where rock cuts 60 feet deep were necessary. Fish Creek Hill is climbed at the base of vertical cliffs 600 feet high, where rock cuts 60 to 70 feet deep and rock fills 75 feet high are necessary. The construction is as expensive as heavy railroad work, the cost of some short portions reaching $25,000 per mile; in others it fell as low as $500 per mile. This road makes it possible to receive freight over two competing lines of railroad. The reduction of rates on oil for burning cement, on food stuffs, on machinery, supplies, hay, grain, etc., will nearly pay the full cost of the road. Indirectly it has opened up a country hitherto absolutely inaccessible. While under construction over 400,000 pounds of freight passed over it.

The road to the timber in the Sierra Ancha has also opened up a new country. Gila County and the inhabitants of Pleasant Valley are extending this road to that valley, where it will connect with the road to Holbrook.

Altogether it has been necessary to construct about 80 miles of road, part of which replaces roads which will be flooded by the reservoir.

CEMENT MILL.

An investigation of the cost of cement delivered at the dam made it seem probable that money would be saved by the construction of a cement mill. Accordingly plans were drawn and estimates made of the cost of a mill capable of producing 300 barrels of cement a day. Bids were called for, and opened on February 29, 1904, for the delivery at Roosevelt of about 200,000 barrels of cement. The lowest price bid was $4.81 a barrel. This was low, considering the 1,000-mile railroad and 40-mile wagon haul. A comparison of these figures with the probable cost of cement as manufactured at the dam shows a saving to the people of the Salt River Valley of several hundred thousand dollars. This estimate is based on an output of only 200,000 barrels, charging the entire cost of the mill against this output, in addition to the probable cost of manufacture.

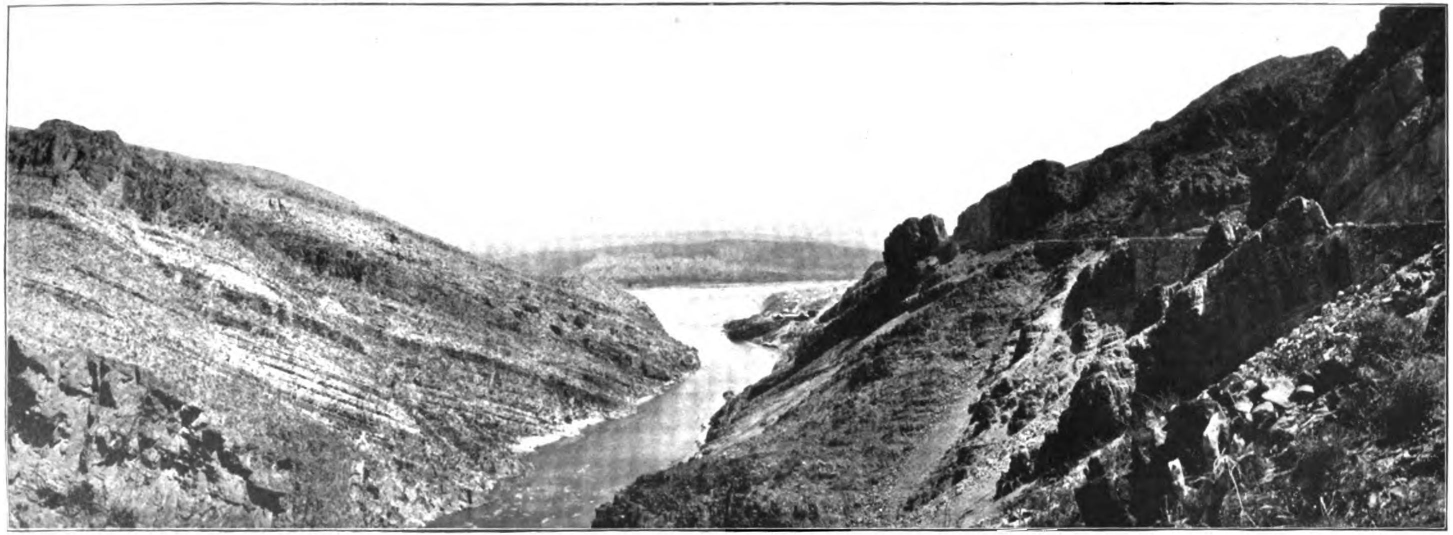
The following is an abstract of the proposals received for the erection of the building for the Portland cement plant:

Bids for erection of steel and timber mill for Portland cement plant on Salt River, Arizona.

	Penn Bridge Co.	Missouri Valley Bridge and Iron Works.	St. Paul Foundry Co.	Joliet Bridge and Iron Co.	Fifield & Gallagher.	M. J. Patterson Construction Co.	Eddie & Greenleaf.
1. Lump sum for entire building erected in place—							
(*a*) Including haulage from Globe	....	....	....	....	$17,500.00	....	....
(*b*) Exclusive of haulage from Globe	$15,000.00	$13,800.00	....	....	16,800.00	$16,331.00	$24,674.00
2. Lump sum for all steel and iron required for entire building, f. o. b. cars	10,640.00	....	[a]$12,300.00	[b]$6,800.00	[a]11,200.00	[c]6,057.00	[a]14,342.00
3. Pound price for furnishing and erecting extra structural materials	.08¼	.07¼	....	....	.10	.08	.15¼
4. Pound price for extra rods, bolts, nuts, cast washers, delivered	[a].06$\frac{1}{16}$	[a].06¼	[a].06	....	[a].11	[c].05	[a].06¼
5. Timber posts furnished by the Government substituted for the steel columns and entire building erected in place	....	....	....	....	....	....	....
6. Building erected only	....	....	....	....	....	....	....

	Champion Iron Co.	Minneapolis Steel and Machinery Co.	American Bridge Co.	Wisconsin Bridge and Iron Co.	Wilcox & Rose.	Allis Chalmers Co.	McClintick-Marshall Construction Co.
1. Lump sum for entire building erected in place—							
(*a*) Including haulage from Globe	....	....	....	....	$13,997.53	....	....
(*b*) Exclusive of haulage from Globe	$14,500.00	....	$15,450.00	$17,340.00	12,997.53	$20,250.00	....
2. Lump sum for all steel and iron required for entire building, f. o. b. cars	[a]11,500.00	[a]$13,200.00	[a]11,000.00	[a]13,120.00	[a]9,700.00	[a]14,063.00	[a]$10,878.00
3. Pound price for furnishing and erecting extra structural materials	.07¼	[a].06$\frac{3}{16}$	.07¼	.09¼	8.73	....	.05$\frac{4}{10}$
4. Pound price for extra rods, bolts, nuts, cast washers, delivered	.....	[a].06$\frac{4}{16}$	[a].06¾	[a].07$\frac{1}{16}$	[a].07	....	[a].05
5. Timber posts furnished by the Government substituted for the steel columns and entire building erected in place	....	....	....	....	11,893.00	....	....
6. Building erected only	[d]	....	....	....	3,300.00	....	....

[a] F. o. b. Globe.
[b] F. o. b. Joliet.
[c] F. o. b. Chicago.
[d] Windows and doors not included.



PANORAMA VIEW FROM POINT ON HIGH-LINE ROAD JUST BELOW ROOSEVELT DAM SITE, SALT RIVER PROJECT, ARIZONA.

Looking directly north up the river into the reservoir site, showing dam site and high line road.

The foundations of the mill were built by day labor, and the building was furnished and erected by Wilcox & Rose, by contract entered into December 17, 1903. (Pl. VI.)

On September 21, 1903, bids were opened at Denver, Colo., for supplying machinery for the cement plant. The following is an abstract of the proposals received:

Bids for machinery for Arizona Portland cement plant, received at Denver, September 21, 1903.

Item.		Jeffrey Manfacturing Co. (f. o. b. Columbus, Ohio).	Vulcan Iron Works (f. o. b. Wilkes-barre, Pa.).	Fairbanks, Morse & Co.	Bonnot Co. (f. o. b. Canton).[a]	Allis Chalmers Co. (f. o. b. Chicago).[b]
1	Wire cable conveyor	$165.00				
2	Parts of drive	81.00				
3	Hopper of clay crusher	18.00				
4	Clay crusher	350.00				
5	Crusher drive	17.50				
6	Helicoidal conveyor	37.50				
7	Clay chute	25.00				
8	Rotary clay dryer	1,400.00	$1,275.00			
9	Rotary rock dryer	1,200.00	1,200.00			
10	Drive for rotary dryers	85.00				
11	Rock crusher chute	40.00				
12	Rock crusher	(c)				
13	Drive of rock crusher	(c)				
14	Chute from crusher	(c)				
15	1 belt conveyer for rock	435.00				
16	Iron frame to carry rock conveyor.	175.00				
17	Drive of rock conveyor	31.00				
18	1 belt conveyor for clay	190.00				
19	Iron frame to carry clay conveyor.	120.00				
20	Drive of clay conveyor	31.00				
21	Countershafts for conveyors	10.50				
22	2 No. 8 ball mills	(c)				
23	Ground limestone elevator	180.00				
24	1 clay mill	(c)				
25	Drive for clay mill	(c)				
26	Weighing machine	(c)			(c)	
27	2 screw conveyors between weighing mill and tube mill	18.50				
28	2 sets wheels and chain for 2 conveyors	85.00				
29	Elevator between bins and tube mill	150.00				
30	2 tube mills	(c)				
31	Elevator to raw mixture bins	105.00				
32	Drive of elevator	12.00				
33	2 helicoidal conveyors and drives.	75.00				
34	Dust chamber conveyors and drives	95.00				
35	Countershaft between kilns	31.00				
36	2 automatic kiln feeders with drive.	(c)				
37	2 rotary kilns	(c)	6,100.00			
38	2 variable speed devices	(c)	600.00			

[a] Total price covers 55 items specified.
[b] Total price covers the entire 57 items specified
[c] Omitted.

Bids for machinery for Arizona Portland cement plant, received at Denver, September 21, 1903—Continued.

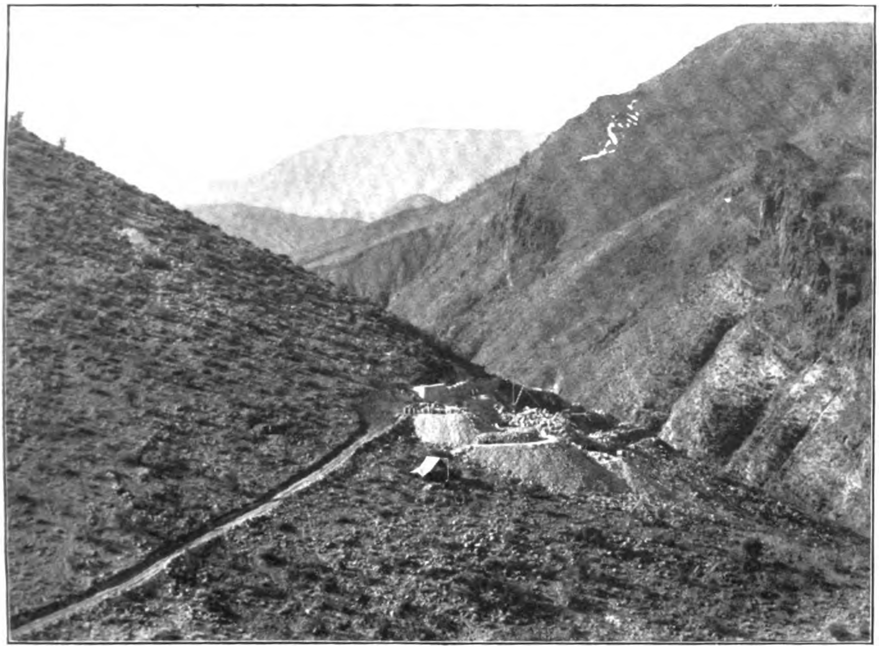
Item.		Jeffrey Manufacturing Co. (f. o. b. Columbus, Ohio).	Vulcan Iron Works (f. o. b. Wilkes-barre, Pa.).	Fairbanks, Morse & Co.	Bonnot Co. (f. o. b. Canton).	Allis Chalmers Co. (f. o. b. Chicago).
39	2 kiln burners	([a])			([a])	
40	1 fan blower and 48 by 6 inch pulley	([a])				
41	Exhaust and discharge blast pipes	([a])				
42	Rotary cooler	([a])	$1,150.00			
43	Blower for cooling clinker and 48 by 6 inch pulley	([a])				
44	1 clinker elevator	$135.00				
45	Vertical clinker tower	([a])				
46	Countershaft	8.50				
47	Conveyor between ball mills and tube mills	30.00				
48	1,000 feet screw pipe and fittings	([a])				
49	Fuel oil piping	([a])				
50	Metal lathing	([a])				
51	200 R. P. M. shaft	139.75				
52	260 R. P. M. shaft					
53	Belting, canvas, and leather	([a])				
54	2,500 feet rails	([a])				
55	7 one-yard cars	([a])		$487.00		
56	Canvas belting	255.00				
57	Leather belting	([a])		878.48		
	Total	5,731.25	10,325.00	1,365.48	$42,000.00	[b]$38,330.00

Item.		Lathbury & Spackman (f. o. b. Chicago).[c]	Chas. A. Shieren & Co.	Webster Manufacturing Co. (f. o. b. Chicago).	F. L. Smidth Engineers (f. o. b. Willoughby, Ohio).	Arthur Koppel.
1	Wire cable conveyor			$233.07		
2	Parts of drive			68.45		
3	Hopper of clay crusher			20.00		
4	Clay crusher			([a])		
5	Crusher drive			4.68		
6	Helicoidal conveyor			30.98		
7	Clay chute			5.95		
8	Rotary clay dryer			([a])		
9	Rotary rock dryer			([a])		
10	Drive for rotary dryers			34.09		
11	Rock crusher chute			40.00		
12	Rock crusher			([a])		
13	Drive of rock crusher			108.96		
14	Chute from crusher			52.00		
15	1 belt conveyor for rock			306.58		
16	Iron frame to carry rock conveyor			210.00		
17	Drive of rock conveyor			18.67		
18	1 belt conveyor for clay			186.78		
19	Iron frame to carry clay conveyor			154.00		
20	Drive of clay conveyor			28.31		
21	Countershafts for conveyors			9.20		

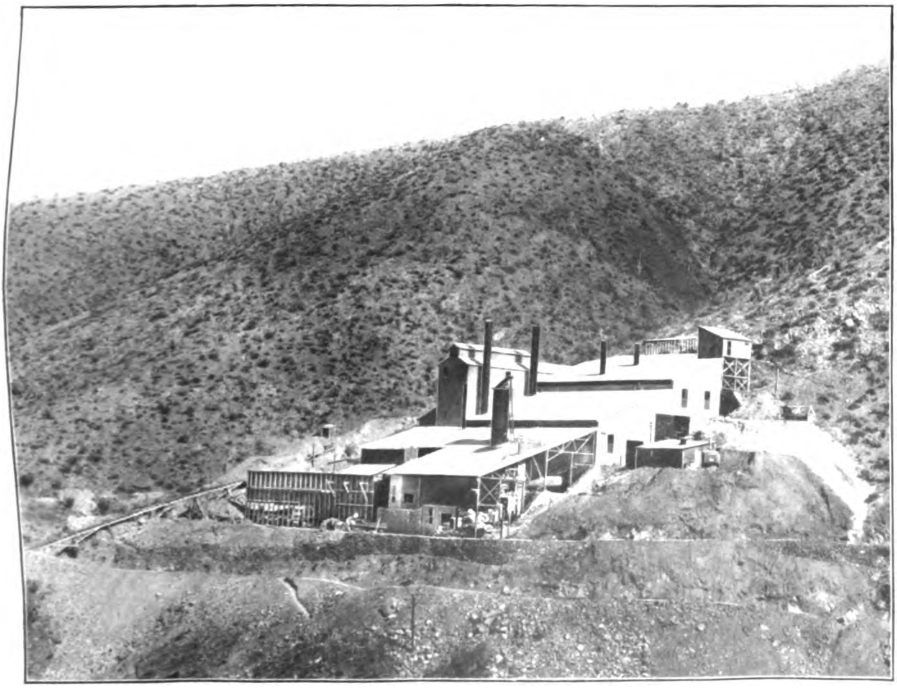
[a] Omitted.

[b] 2 cut steel pinions, $82; for joining shells, $90; extra for 7 foot kilns, $296. Total, $38,798.

[c] Total price covers the entire 57 items specified.



A. VIEW SHOWING TOPOGRAPHY AT CEMENT PLANT AND ROADWAY LEADING UP TO PLANT FROM CAMP, SALT RIVER PROJECT, ARIZONA.



B. COMPLETED CEMENT PLANT, SALT RIVER PROJECT, ARIZONA.

Bids for machinery for Arizona Portland cement plant, received at Denver, September 21, 1903—Continued.

Item.		Lathbury & Spackman (f. o. b. Chicago).	Chas. A. Shieren & Co.	Webster Manufacturing Co. (f. o. b. Chicago).	F. L. Smidth Engineers (f. o. b. Willoughby, Ohio).	Arthur Koppel.
22	2 No. 8 ball mills			(a)		
23	Ground limestone elevator			$68.67		
24	1 clay mill			(a)		
25	Drive for clay mill			104.13		
26	Weighing machine			(a)		
27	2 screw conveyors between weighing mill and tube mill			89.78		
28	2 sets wheels and chain for 2 conveyors					
29	Elevator between bins and tube mill			45.71		
30	2 tube mills			(a)		
31	Elevator to raw mixture bins			86.55		
32	Drive of elevator			10.31		
33	2 helicoidal conveyors and drives			63.02		
34	Dust chamber conveyors and drives			119.90		
35	Countershaft between kilns			23.14		
36	2 automatic kiln feeders with drive			(a)		
37	2 rotary kilns			(a)		
38	2 variable speed devices			(a)		
39	2 kiln burners			(a)		
40	1 fan blower and 48 by 6 inch pulley			(a)		
41	Exhaust and discharge blast pipes			(a)		
42	Rotary cooler			(a)		
43	Blower for cooling clinker and 48 by 6 inch pulley			(a)		
44	1 clinker elevator			125.09		
45	Vertical clinker tower			(a)		
46	Countershaft			17.35		
47	Conveyer between ball mills and tube mills			24.85		
48	1,000 feet screw pipe and fittings			(a)		
49	Fuel oil piping			(a)		
50	Metal lathing			(a)		
51	200 R. P. M. shaft			102.62		
52	250 R. P. M. shaft			131.04		
53	Belting, canvas and leather			(a)		
54	2,500 feet rails			(a)		[d] $613.75
55	7 one-yard cars			(a)		395.00
56	Canvas belting		$225.00	253.27		
57	Leather belting		770.00	787.45	[b] $15,600.00	
	Total	$59,958.98	995.00	3,567.52	[c] 15,600.00	1,008.75

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[a] Omitted.

[b] Two comminuters and two tube mills only.

[c] Equivalent to numbers 22 and 30.

[d] Approximate.

Under date of December 22, 1903, contract was entered into with the Allis-Chalmers Company, of Chicago, Ill., for supplying the machinery, which is to be erected by the United States. The mill is run by induction motors, to which current will be furnished from the temporary power plant. This mill is in charge of E. Duryee.

HYDRAULIC GATES, SALT RIVER PROJECT.

A tunnel about 500 feet long has been driven through the side walls of the canyon at the dam. In this tunnel will be placed six gates to be used for sluicing purposes and for regulating the flow of water to the canals in the Salt River Valley, about 50 miles below. These gates with their operating mechanism, etc., will weigh nearly 800,000 pounds, and will be the largest ever constructed to operate under the great pressure of 100 pounds per square inch. The pressure on each gate is about 800,000 pounds. With the reservoir full, these gates are capable of discharging 10,000 cubic feet per second. During the construction of the dam the river will be diverted through this tunnel. (Pls. VII and VIII.)

The plans and specifications for the construction of these gates were prepared under the direction of the project board of engineers by F. Teichman. Bids were opened on October 1 at Denver, and the contract awarded to the Llewellyn Iron Works, of Los Angeles.

ROOSEVELT DAM.

Plans and specifications have been prepared and bids for the construction of the dam will be opened at Phoenix on February 8, 1905.

This dam will be located in the canyon of Salt River, just below the mouth of Tonto Creek, and will impound about 1,100,000 acre-feet of water. Two spillways, each about 200 feet long, carry the flood waters around the dam. A roadway is carried over the dam, crossing the spillways on concrete steel-arch bridges. The general plan, elevation, and section are shown on Pl. IX. The general dimensions of the dam are as follows:

Dimensions of Salt River dam, Arizona.

	Feet.
Height of spillway above datum, or mean low water	210
Height of roadway above datum, or mean low water	230
Total height of the dam from lowest point of foundation to top of parapet, about	270
Length of dam at datum	210
Width at roadway	16
Width at base, about	165

Masonry to be used in structure, about 300,000 cubic yards.

The specifications require the building of a masonry dam constructed of broken range cyclopean rubble laid so as to break joints and thoroughly bonded in all directions. The stone will be quarried from the walls on each side of the canyon and from the spillways, and will be laid up in cement mortar. That for the upstream face will be selected so as to lie with horizontal beds and vertical joints in Portland-cement mortar composed of one part Portland cement and two parts sand. It is contemplated that the work shall be carried on continuously, day and night, until the dam has reached the height of 150 feet. The electricity for lighting will be furnished free by the United States, and power will be furnished the contractor at a low rate from the temporary power plant. The dam is built on a curve having a radius of about 400 feet. This dam will back the water up Salt River about 16 miles and up the Tonto nearly as far. It will produce a lake somewhat over 25 miles long and from 1 to 2 miles wide. The reservoir will have a capacity greater than that of any other artificial reservoir in the world.

The general specifications (sections 1-38) for the construction of *this* dam are similar to those provided for other work. The detail specifications are as follows:

39. *Diversion.*—Floods exceeding 4,000 second-feet are liable to go over the dam. The river, at low stage, shall be diverted through the tunnel or temporary flume by means of a temporary diversion dam not less than 12 feet high above the bottom of the tunnel, and made as tight as practicable with sheet piling securely connected with the dam. The stream shall be conducted well below the vicinity of the dam before discharging into the river. A row of sheet piling shall also be driven across the canyon below the dam site to prevent the return of water by seepage. As soon as practicable a tight wooden flume, not less than 50 feet wide and 5 feet deep, shall be provided, leading from a level 5 feet below the top of the diversion dam and discharging below outlet of tunnel. The construction of dams, cofferdams, flumes, and all other diversion and protection works shall be done at the contractor's cost without extra compensation. The necessary lumber for such works will be furnished, after due notice, by the United States at the dam site at the rate of $25 per M feet board measure, the charge therefor to be deducted in the monthly statements of amounts due the contractor. No sawed lumber over 22 feet in length can be furnished.

40. *Excavation.*—All material will be measured in place, and the material excavated from the foundation shall be paid for in three classes, viz:

Class 1. Loose material consisting of sand, gravel, and bowlders of less than 10 cubic feet, and all other material which may occur excepting solid rock in place.

Class 2. Solid rock in place, lying below the datum, which is about low-water surface, and bowlders of 10 cubic feet or larger.

Class 3. Solid rock in place above the datum.

41. *Foundation.*—The foundation shall be thoroughly cleaned of all gravel, sand, and earth, and all fissured or disintegrated rock shall be removed so that the dam shall be founded on solid rock throughout, and in such manner as required by the engineer in charge. Explosives shall not be used in excavating the rock in the foundation unless absolutely necessary; and when used, shall be in small quantities only, and in a manner approved by the engineer. A trench shall be cut in the solid rock of the foundation 15 feet from the heel of the dam, and parallel thereto, and shall be 10 feet wide and 6 feet deep below the bottom of the dam on the line of the trench.

42. *Removal of temporary works.*—All cofferdams or other temporary works shall be removed by the contractor, free of cost, at such times as the engineer may direct.

43. *Side walls.*—Above the bed of the river the side walls shall be cut away until they present surfaces normal to the face of the dam, suitable, in the judgment of the engineer, for solid and safe junction with the masonry. This shall be paid for by the cubic yard as solid rock at the price agreed upon in the contract; any earth or loose material occurring in the side walls will be small in amount and shall be removed by the contractor without extra charge.

44. *Overhaul.*—All material excavated from the foundations and side walls shall be placed where directed by the engineer. Whenever the engineer may require any material transported more than 300 feet from the point of excavation the distance over 300 feet will be paid for as overhaul at the price agreed upon in the contract.

45. *Masonry.*—The main body of the dam shall be constructed of broken range cyclopean rubble, laid so as to break joints and thoroughly bond the work in all directions. The stone shall be quarried from the walls on each side of the canyon shown in the drawing as proposed spillways. If a sufficient quantity of hard fine-grained stone can not be obtained in these spillways it shall be quarried from the bluffs at either end of the dam at locations designated by the engineer, at the contractor's expense. Each stone shall be thoroughly drenched and cleaned of dirt and laid in Portland cement mortar of the quality hereafter specified. Vertical joints between the stones inside of the face stone of the dam must be nowhere less than 6 inches, and must be thoroughly filled with Portland cement concrete, or mortar, which should be rammed into place by hand, to the end that all space in the dam not occupied by stone shall be absolutely filled with mortar. Spalls may be rammed into the mortar in the vertical joints and rock may be rammed into the concrete where the joints are large enough. No rock shall come nearer to another than 2 inches. All overhanging edges shall be hammered off, and concave or otherwise improper beds are prohibited. The aim shall be to use the largest proportion of stone and the smallest proportion of mortar and concrete in the dam that can be practically secured. To this end facilities shall be provided for handling stones weighing 10 tons, and large stones shall be used as far as practicable.

46. *Water pipes.*—The contractor shall provide water pipes on the work, by which at any time any portion of the masonry may be thoroughly wet, and these shall be used whenever required by the engineer. All masonry shall be kept wet during the time of construction and until the work is at least six days old.

47. *Upstream face.*—The stone for the upstream face shall be selected so as to lie with horizontal beds and vertical joints in Portland cement mortar, composed of 1 part cement to 2 parts sand. No mortar joint in the face shall exceed 2 inches in thickness. At least one-third of the area in the face must be headers evenly distributed throughout the wall, and every header shall be laid over a stretcher of the underlying course. The stone shall be so arranged as to break joint in no case less than 1 foot with the stone of the underlying course. The stretchers must be not less than 3 feet long nor less than 2 feet in any other dimension; the headers must not be less than 6 feet in length nor less than 2 feet in any other dimension. The joints in this face of the dam shall be dug out to a depth of at least 3 inches and at such times as directed shall be carefully pointed by hand with mortar composed of equal parts of sand and cement, or with such material as shall be required by the engineer and furnished by the United States, and this shall be done as thoroughly as possible in order to make a water-tight surface. Immediately before pointing, the joints shall be thoroughly washed out with a hose. Projections of 12 inches or less beyond the lines of the drawings will be permitted where they are of such symmetry as not to be unsightly. The face wall shall be kept at all times at least one course higher than the body of the dam opposite.

48. *Downstream face.*—The stone for the downstream face shall be so selected as to lie with horizontal beds and vertical joints, and each stone shall be laid in a bed of cement mortar composed of sand and cement in the proportion directed by the engi-

neer; where not otherwise directed the proportions shall be 1 part of cement to 2½ parts of sand. At least one-fourth of the area in the face must be headers, evenly distributed throughout the wall, and every header shall be laid over a stretcher of the underlying course. The stone shall be laid in steps and shall have a proper bond with the stone of the underlying course. Projections of 2 feet or less beyond the lines of the drawing will be permitted where they are of such symmetry as not to be unsightly. Payments will be made in every case for material within the neat lines of the drawing only. The face wall shall be kept at all times at least one course higher than the body of the dam opposite.

49. *Wing walls.*—Two rubble-masonry wing walls of the same character of masonry as the body of the dam shall be constructed as shown in the drawings. The dimensions of these wing walls are dependent on the character of the rock, and can only be accurately determined when the excavation is complete.

50. *Outlet pipes.*—The United States reserves the right to require the insertion, in such manner as the engineer may direct, of large pipes for drawing water through the dam. All pipes to be built in the dam will be furnished by the United States at the dam site, and shall be built in by the contractor. The price of laying to be included in the price for masonry, and paid for by the cubic yard at the same rate as masonry.

51. *Coping, etc.*—The coping, roadway, guard walls, bridge piers, bridges, gate shaft, and spillways shall be built and finished in a workmanlike manner, as shown in the drawings. The contractor shall insert, in the position and manner designated by the engineer, such iron or steel as may be required and furnished by the United States.

52. *Concrete.*—All concrete used in the dam shall be composed of Portland cement, sand, and broken stone, in the proportion by volume directed by the engineer. The run of crusher will be taken, the parts passing a ¼-inch screen being classed as sand. The sand shall be free from organic matter, and contain not more than 10 per cent of clay or other foreign mineral substance. Where not otherwise directed, the proportions of separate aggregates shall be 1 part of cement, 2½ parts sand, and 4 parts of broken stone of such size as to pass through a 2-inch-mesh screen.

53. *Sand.*—The contractor shall provide screens for ascertaining the proportion of materials of various sizes produced by the crusher, in order to enable the engineer to determine the necessary proportion of sand in the concrete; and he shall at intervals, when required, make such tests as may be necessary for this purpose without extra charge. Sand required in addition to the run of the crusher, or such substitute as the engineer may adopt, will be furnished by the United States at the dam site, without cost to the contractor.

54. *Mixing.*—The mixing shall be done by a machine whenever practicable, and the style of machine shall be subject to approval by the engineer. Whenever the machine fails to perform the mixing thoroughly it must be made satisfactory or removed and another machine substituted. When from any cause resort to hand mixing is necessary, this shall be done thoroughly and to the satisfaction of the engineer.

55. *Water.*—The water used for mixing must be free from organic matter. The amount of water used both in mixing and seasoning the concrete after it is placed in the work must be satisfactory to the engineer. All concrete will be used as wet as will give good results and as the nature of the work will permit.

56. *Cement.*—All cement will be furnished by the United States and will be delivered to the contractor near the cement mill in Tonto Basin.

57. *Time of beginning work.*—Within twenty days after receipt of contract for signature the successful bidder shall execute the same and file a satisfactory bond. Within thirty days after notice of signature of contract by the Secretary of the Interior, the contractor shall begin work under the contract, and within ninety days

thereafter shall have on the work as large a force as can be economically employed, and a plant adequate to prosecute the work in the most rapid and efficient manner practicable, and carry it to completion as specified in the proposal. He shall employ three daily shifts of eight hours each on masonry construction, and shall provide an ample number of electric lights to efficiently illuminate all work in progress at night. The number of lamps and the type thereof shall be subject to the approval of the engineer.

58. *Default.*—Should the contractor fail to begin the work within the time allowed, or fail to begin the delivery of material as provided in the contract, or fail to prosecute the work or delivery in such manner as to insure a full compliance with the contract within the time limit, or default in any other manner in the proper execution of the work, all the machinery, tools, appliances, and animals employed on any of the works to be constructed under the contract, and all materials belonging to the contractor delivered on the ground, shall be and become absolutely the property of the United States.

59. *Deduction for failure to complete.*—Bidders will state in their proposals the time in which they propose to complete the dam to a height of 150 feet above the datum, which datum is about low-water mark. Time is an element in the construction of this work, and will be considered in the examination and comparison of bids and the award of the contract therefor. If the work is not completed within the time agreed upon in the contract there will be deducted from all payments made on said work after the expiration of said time the sum of $250 per day for every day occupied in excess of the time agreed upon in the contract, as liquidated damages for the loss to the Government on account of engineering, superintendence, and the value of the operation of the irrigation works dependent thereon, said sum to be deducted from any amount due under the contract.

60. *Completion.*—After the completion of the dam to the 150-foot level, it shall be discretionary with the engineer whether masonry work on the dam be permitted during the months of June, July, August, and September, but work shall be prosecuted vigorously and continuously during the remaining eight months of the year, at a rate per month of not less than two-thirds of that achieved during the construction of the lower portion of the dam, considered in cubic yards of masonry laid. The contractor shall place in the masonry such iron and steel in such manner as the engineer may direct. The metal will be furnished at the dam site by the United States. The United States reserves the right to vary the section of the dam above the 150-foot level. The section shown on drawings is for comparison of bids only.

61. *Power plant.*—The United States reserves the right to construct a power plant at or near the location shown in the drawings without hindrance from the contractor. The power house may be built by the same contractor as the one building the dam, by another contractor, or by the United States, as may best conserve the public interests. After the work on the power plant is begun, that portion of the dam adjacent to the left bank must be kept at least 10 feet higher than the rest of the dam, as a protection to the power house in case of overflow. The United States reserves the right to store and use the water in the reservoir up to a level 25 feet below the lowest point of the top of the masonry.

62. *Power.*—Electric energy for all lights for construction purposes will be furnished free of charge at the dam. Electric energy for all power purposes required by the contractor will be furnished at the dam, to be measured at the power plant and charged for at the rate of ½ cent per horsepower hour up to a limit of 400 horsepower, and 1 cent per horsepower hour for all power in excess of 400 horsepower, the charges therefor to be deducted in the monthly statements of amounts due the contractor. The United States does not guarantee the delivery of more than 600 horsepower.

63. *Repairs.*—Repairs required by the contractor will be performed when feasible

in the repair shop attached to the cement mill, and will be charged at cost for necessary labor and material plus 15 per cent for use of tools.

64. *Payment of employees.*—The contractor shall make such banking arrangements that his employees may not be subjected to loss in securing their wages.

65. *Payments to contractor.*—Payments will be made to the contractor as follows: At the end of each calendar month the engineer shall make an approximate measurement of all the work done up to that date, and an estimate of the value of the same at the prices agreed upon in the contract. A deduction of 20 per cent shall be made from this estimated amount, and from the balance shall be deducted the amount of all previous payments. The remainder shall be paid to the contractor upon the presentation of proper accounts. The 20 per cent so deducted shall be retained by the Government until the work shall have been completed to the entire satisfaction of the chief engineer and the Secretary of the Interior, and then be payable to the contractor, his heirs, assigns, or legal representatives; provided, however, that in the event of default on the part of the contractor all of the moneys retained under this paragraph in the hands of the Government shall be and become absolutely the property of the United States in reimbursement of any damage which may result through the failure of the contractor to fully and satisfactorily comply with the terms and conditions of his contract. After 50 per cent of the work shall have been completed the foregoing deduction of 20 per cent shall no longer be made, but the contractor shall be paid the full value of the work done during each month. The balance due upon completion of the work shall be paid as provided in paragraph 36.

POWER PLANTS.

A power plant will be built at the foot of the dam, to contain hydraulic and electric machinery for utilizing both the energy from the power canal and that stored in the water in the reservoir.

It is contemplated that the water in the reservoir will be drawn down to the 80-foot level through pipes connecting with water wheels. The power so developed will be transmitted from 50 to 70 miles to Salt River Valley and there used for operating centrifugal pumps. These pumping plants will be distributed over the valley in such locations as will furnish the largest supply of water and best serve the requirements. With the water at its present horizon each horsepower developed at the dam will furnish power sufficient to pump water to irrigate nearly 10 acres in the valley 60 miles away.

At a point about 7 miles below the dam there is an excellent site for a small power plant. A short diversion dam, a tunnel of 300 feet, and a canal about 2 miles long will make available a head of about 70 feet. After the reservoir is constructed this will furnish about 3,000 horsepower. Taken in connection with the power developed at the dam, about 50,000 acres can be irrigated, provided sufficient underground water can be developed. The cost per horsepower of this plant will be materially less than for any other which may be constructed along Salt River, but the total power here available is not alone sufficient for the development of the area to be irrigated from the subterranean waters.

About 25 miles below this point a great bend in the river makes it possible to develop 2,000 horsepower by building a low-diversion dam and driving a tunnel 3,500 feet long. If the tunnel be driven large enough to carry the full discharge, enough power can be developed to irrigate about 15,000 acres during most of the year. A steam auxiliary plant, costing but a small amount per acre, could furnish power during such time as the gates in the reservoir were closed.

The building of this plant would solve the question of power for pumping water for irrigation on the Gila River Indian Reservation and would keep the entire control of the power developed at this point in the hands of the Indians.

Early this year Andrew Weiss, assistant engineer, was intrusted with the location of a power canal just above the mouth of Verde River. A careful location through a very difficult country was made. A canal about 10 miles long made available a head of 91 feet.

After the dam is built the discharge of the river for the greater part of the year will average 400 second-feet, which will furnish about 4,100 horsepower to the water wheels. The combined electric and hydraulic plant will deliver about 3,000 horsepower, net.

The hydraulic development will cost about $150 per horsepower delivered by the water wheels. If future operations show the existence of sufficient underground water, the construction of this plant will be amply justified.

UNDERGROUND WATER OF SALT RIVER VALLEY.

It is intended to utilize the power developed at the dam, both from the reservoir and the power canal, for pumping the underground waters of the Salt River Valley. This water will be used for irrigating in the district not covered by canals. If sufficient water can be developed it is proposed to construct additional power plants along the river, so as to utilize all the available water for irrigation. A number of private pumping plants are now at work in the valley and have proved their value during the dry seasons. Enough water, however, is not used by the combined plants to appreciably affect the level of the underground water, so that no exact estimate can be made of the total quantity available for irrigation.

A study of the conditions in and about Salt River Valley, with a view to ascertaining the amount of such water, has been made by Willis T. Lee, assistant geologist. From this it appears that Salt River Valley was at some former time a broad, deep valley surrounded by granite mountains. This valley was later filled to a great, though unknown, depth by clay, sand, gravel, and bowlders. The loose material is kept saturated with water, probably by the river and by the occasional floods entering the valley from the surrounding hills.

In this valley there are at least three water-bearing horizons—first, the so-called surface flow; second, the so-called underflow, the great water-bearing horizon of the valley, extending down to a depth of about 200 feet or more, and separated from the surface flow by an impervious clay layer, and, third, a water-bearing sand that yields a large amount of water. Only two wells have been put down below the second horizon. One struck the third horizon at 600 feet. The second well, 705 feet deep, did not strike a third water horizon. Neither reached bed rock.

The waters in the lower horizons are under pressure and rise in the wells nearly to the surface. Water from the lowest horizon rises nearer the surface than water from the horizons above. Other water-bearing horizons may exist which have not been exploited up to the present time, and these may contain large supplies.

In the two wells above mentioned the formation below the 200-foot level is mostly clay. The fact that in one case an important water-bearing sand exists in the midst of the clay strengthens the supposition, arrived at from a study of the nature of the valley fill, that other horizons may be found. There is, furthermore, the possibility that wells penetrating lower horizons might give an artesian flow. In the San Pedro Valley, Arizona, where conditions are similar to those in Salt River Valley, an artesian flow is obtained from beneath a mass of clay 700 feet or more in thickness.

In the 1,305-foot well the clay of the valley fill is known to extend below sea level. The surface elevation is 1,225 feet, thus placing the bottom of the well 80 feet below sea level. Any sand or gravel beds, therefore, found at or near the bottom of the valley fill would almost certainly be saturated with water, since no water could drain out.

It is proposed to use the power generated at the projected reservoir to pump water from the underflow in the valley, and thus augment the supply made available for irrigation by the storage of the flood waters. With this end in view the geologic, physiographic, and economic conditions relating to the underground water supply have been studied, and the ways and means of rendering it available for irrigation have been investigated.

The areas over which investigations have been extended are generally known as Salt River Valley and Gila Valley. Salt River Valley, taken in this sense, extends along Salt River from Verde River to Gila River. Gila Valley extends from the Buttes east of Florence to the junction of Gila and Salt rivers. The valleys are not separate in the sense that there is any well-defined line of division between them, nor are they definitely separated from the desert plains into which they merge. The investigations were confined to such areas near the river as were available for irrigation and such neighboring areas as had to do directly with this problem. The region thus examined has an area of about 1,800 square miles.

The geology of the region has been studied in order to ascertain the bearing of stratigraphy and structure on the occurrence of underground waters. For this purpose the character and general areal distribution of the formations have been determined in regions likely to be sources of underground supply. The physiography of the region has received careful attention. The study of the form and the extent of the débris-filled ancient valleys and of the structure and character of the valley fill has given much information concerning the best locations for pumping plants.

No flowing wells have been found in the region under consideration, and there is but little hope that such wells will be obtained.

Beneath a large area in Salt River Valley and also in the Gila Valley, including the greater part of the Pima Indian Reservation, underground water is less than 50 feet beneath the surface of the ground.

The quantity of water obtained by pumping in the best localities has thus far been limited only by the capacity of the pump. Pumping plants which are raising water at a rate sufficient to irrigate 1,000 acres of land have not succeeded in permanently lowering the water level to any measurable extent.

After due consideration of all available facts, there seems to be little doubt that in Salt River Valley sufficient water to increase the irrigated areas to a notable extent may be obtained by pumping.

The underground waters contain large quantities of salts. It is probable, however, that the water can be so treated as to render useful for irrigation even that which is most highly charged.

In Gila Valley enough underground water is probably available near the surface to supply the present needs of the Indian Reservation in that valley.

Complete report of the investigations of the underground waters made by Willis T. Lee, under direction of N. H. Darton, may be found in Water-Supply and Irrigation Paper No. 104.[a]

CHEMICAL INVESTIGATIONS OF WATERS IN SALT RIVER VALLEY.

A chemical investigation of the underground waters of Salt River Valley has been carried on during the last few months by Sheldon K. Baker, under the general direction of M. O. Leighton. This shows a gradual increase in the salt contents from the Arizona dam to the lowest point investigated, about 40 miles below.

The water from 385 wells, of which 338 were less than 100 feet deep, has been analyzed, and a map showing the salt distribution by isochloric lines has been drawn.

An investigation into the sources of the salt in the Salt River shows that probably 60 to 70 per cent of it comes from Carrizo Creek, which enters the river about 70 miles above the dam. Investigations as to the possibility of preventing the salt from entering the river are being carried on.

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[a] Underground waters of Gila Valley, Arizona.

The information obtained from these investigations, it is hoped, will lead to a better use of these waters and to the adoption of means to increase the value of those carrying the highest percentages of salt and alkali.

VERDE RIVER RESERVOIR.

The waters of Verde River enter Salt River just above the head of the Arizona canal. The waters of this stream are much fresher than the Salt and the flow in the river is but slightly less. The water from these two streams will furnish the supply for irrigating the Salt River Valley. Whenever there is sufficient water in the Verde the entire flow of the Salt will be retained in the reservoir. It is intended as part of the complete project to construct a reservoir of about 200,000 acre-feet capacity on Verde River, thus saving its flood waters and increasing the area which can be irrigated from this river, as well as the length of time water can be stored in Salt River reservoir.

During the present winter careful investigations and estimates will be made as to the possibility of constructing a reservoir on this stream. Two localities have been investigated, one known as the Horseshoe reservoir and the other as the McDowell reservoir. Each has a capacity of about 200,000 acre-feet.

The average yearly discharge of Verde River, computed for a period of fourteen years, is about 500,000 acre-feet; the average for the past five years is under 300,000 acre-feet. The river is subject to heavy floods.

The complete utilization for irrigation of all the water flowing in Salt and Verde rivers would require a reservoir on each stream, and pumping plants to conserve the underground waters of the valley. To get the best results from this water it will be necessary to have a complete system of distributing canals and laterals, so laid out and constructed as to reduce seepage and evaporation to a minimum.

The absolute control of the apportioning of this water should finally be in the hands of the water users' association.

SAN CARLOS PROJECT.

The investigation of water storage upon Gila River was begun in 1895, by Arthur P. Davis, in connection with the problem of irrigation upon Gila River Indian Reservation. At that time pumping tests were made at various points on the reservation, and it was ascertained that a large quantity of water could be obtained, but the scarcity and high price of fuel prevented an adoption of this plan for the relief of the Indians.

Surveys and preliminary soundings were made at Buttes, on Gila River, about 16 miles above Florence, and at Whitlow's ranch, on

Queen Creek. Investigations showed, however, that the water supply for the Queen Creek basin was insufficient for the purposes in view, and in the report (Senate Executive Document, No. 27, Fifty-fourth Congress, second session) it was recommended that an appropriation be made for further investigations, and especially for borings at the dam site on Gila River.

Subsequently an appropriation for this purpose was made, and borings were made at Buttes, Queen Creek, Riverside, and San Carlos during the first half of the year 1899. Before the completion of the borings at San Carlos the state of the finances necessitated the discontinuance of the work, which was stopped in July, 1900.

In August of the same year Mr. Davis was ordered to conduct the hydrographic investigations upon the proposed canal routes in Nicaragua and Panama, and the preparation of a report upon the Gila River problem was assigned to J. B. Lippincott, who had aided in the investigations. The results were published in 1900 as Water-Supply and Irrigation Paper, No. 33.[a]

A dam on Gila River about 5 miles below San Carlos will create a reservoir of great capacity and flood a large tract of country. Investigations as to the flow of this river and the amount of silt carried have been conducted for some years, and it has been ascertained that the Gila carries enormous quantities of silt which would be deposited in the reservoir.

During the past summer investigations have been made on the upper Gila and its branches by W. A. Farish, and two reservoir sites have been located, one on San Francisco River and the other at Red Rocks. The amount of silt carried by the water at these points forms a far smaller percentage than at San Carlos. Further investigations as to the flow will be carried on for some time.

For the satisfactory operation of the San Carlos reservoir it is necessary that auxiliary reservoirs above should be provided, and these investigations seem to make it probable that such reservoir sites have been discovered.

Much of this stored water can be utilized in Gila Valley before reaching San Carlos, except at such time as it is necessary to use it for sluicing out the silt from the latter reservoir.

One of the principal objects of the San Carlos project has been to supply water for the Gila River Indian Reservation. It has been found, however, that water can be pumped for the use of these Indians more economically than it can be stored, and a pumping plant has already been installed, and is in successful operation at Sacaton. The quality of the water is excellent, and the crops raised during the season of 1904 have been notably good. The pumping plant was constructed under the supervision of Indian Inspector W. H. Code. Water is drawn from five wells, and the amount obtained is sufficient to irrigate 250 acres of alfalfa or other crops, if pumped nine hours a day for six days of the week. If operated continuously 600 acres could be supplied. The fuel used is wood, three cords mesquite being sufficient for a twenty-four hour run.

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[a] Storage of water on Gila River, Arizona.

The investigations carried on by Mr. Willis T. Lee, and mentioned on page 154, indicate that there is a large supply of water underground, and that other pumping plants can be successfully erected.

The principal question is that concerning the cost of fuel. It is proposed to obviate the use of fuel continuously by obtaining electric power from the power plant at Roosevelt dam, or probably from independent power stations to be constructed on Salt River below the Roosevelt dam. Plans are being made toward this end, and if suitable authority can be obtained from Congress it is probable that an ample supply of water for the Indians of this reservation can be had at reasonable expense.

SAN PEDRO PROJECT, ARIZONA.[a]

The San Pedro project is located in the southeastern part of Arizona, along San Pedro River, near Benson, Cochise County. (Pl. X.)

The river is torrential in character, and the project contemplates the construction of a dam below Charleston station, on the El Paso and Southwestern Railroad, on San Pedro River, for the storage of the flood waters of the river and the diversion, by means of canals, of the stored water for the irrigation of lands below.

DESCRIPTION OF SAN PEDRO RIVER VALLEY.

A valley averaging 2½ miles wide on either side of the river lies along the San Pedro, extending from 10 miles south to 7 miles north of Benson. It is bounded on either side by a bench composed of a clayey loam and gravel, evidently deposited by water, and then gradually eroded by floods of the river and washed from either side until the present configuration was produced. The tops of the benches are rolling mesas, which slope gradually up toward the Dragoon Mountains on the east and the Whetstone Mountains on the west of the valley. These mesa lands are of a very rich alluvial character, and back from the bench where they are not cut up by washes they are very smooth, so a quick reconnaissance was made to ascertain the feasibility of irrigation. From this it appeared that most of the land was higher than the present reservoir site, making irrigation impossible. It was afterwards learned, however, that the available lands of good quality were far in excess of the water supply or the capacity of the reservoir.

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[a] From report by Henry R. Evans

The valley is composed of as rich land as can be found in this section of the country, with little or no alkali to interfere with its cultivation. It is almost all taken up and partly cultivated. It is being irrigated by means of two small canals, both on the east side of the river, and by artesian wells. The canals are very crudely built by the settlers themselves, being diverted from the river by dams composed of brush and sacks filled with dirt, which go out every summer when the floods come.

The artesian wells are drilled by the crudest implements imaginable, which the farmer has devised himself. They average in depth from 200 to 900 feet and in flow from 3 to 70 gallons per minute. The wells are deepest in the vicinity of Benson and decrease in depth up the river. For the last year the Tombstone Consolidated Mines Company have been pumping at the rate of 1,000 gallons per minute. This, however, does not seem to affect in the least the flow of the wells. The land is very productive, and when irrigated produces peaches, strawberries, watermelons, and, in fact, almost all fruits; five crops of alfalfa are cut annually, and all kinds of vegetables are raised. More than $2,000,000 worth of garden products are shipped annually through Benson to the cities and towns of Bisbee, Douglas, Naco, Cananea, and Nogales.

The catchment basin which drains into the San Pedro above the reservoir is roughly estimated at 1,200 square miles, 500 of which are in the United States and the remaining 700 in Mexico. It is important to know if the water that falls in Mexico will be used in future years by people of that country.

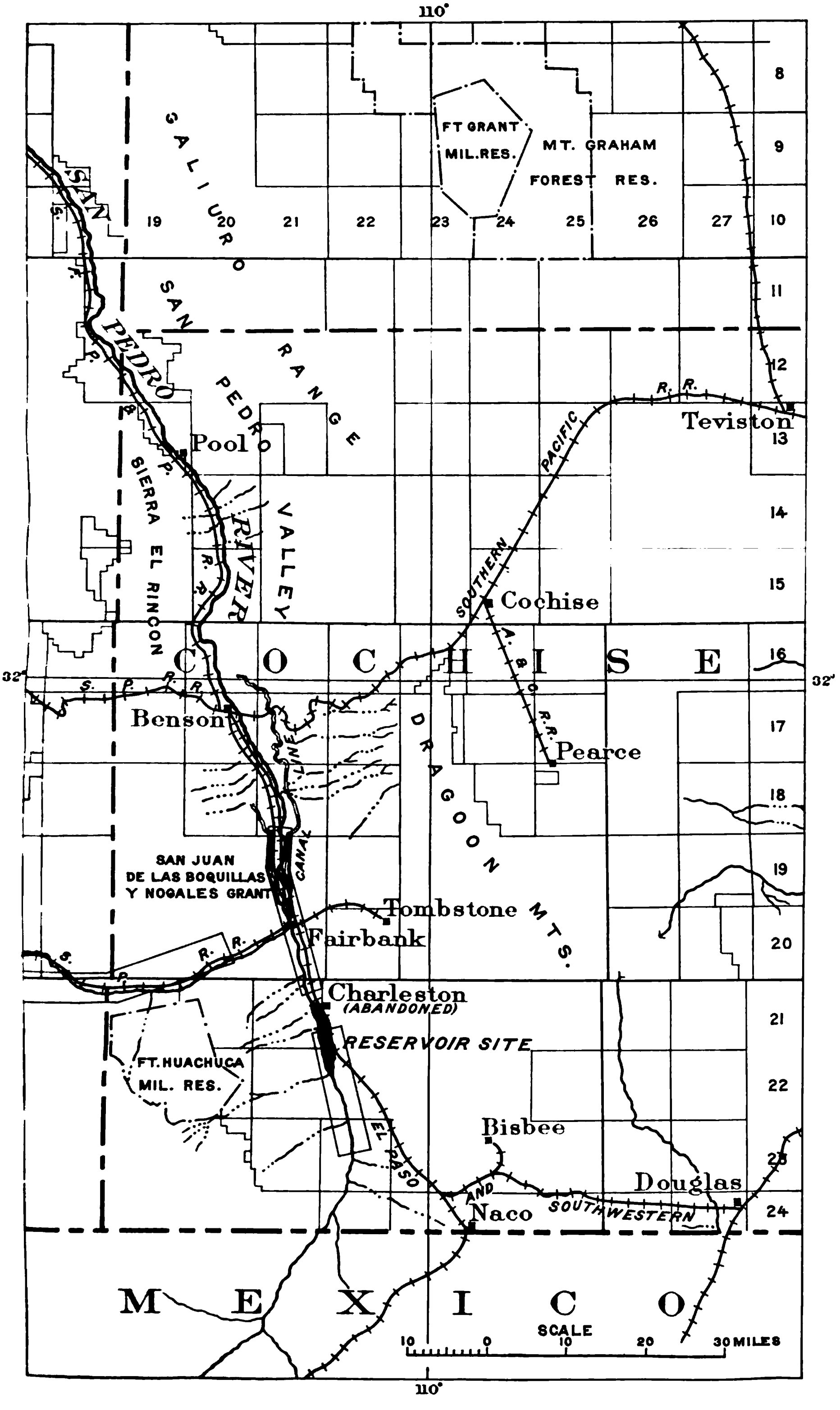
A permanent gage at Charleston has been established, and a resident observer, Mr. H. R. Fry, whose post-office address is Fairbanks, has been appointed.

RESERVOIR.

The site of the proposed reservoir is located on San Pedro River at the old abandoned town of Charleston, on the line of the El Paso and Southwestern Railroad, about 28 miles south of Benson and 8 miles west of Tombstone.

About 1,500 feet north of Charleston station there is a gorge on the San Pedro which is about 150 feet wide at the bottom and 590 feet wide 120 feet above the bottom. The banks are composed of solid basalt. It is proposed to construct the dam here.

The reservoir site has been mapped on a scale of 1,000 feet to 1 inch, with 10-foot contour intervals to 100 feet above the bottom of the dam site, the datum being mean sea level as taken from a United States Geological Survey permanent bench mark at Charleston station, marked 3954. The river bottom at the site of the proposed dam was found to be at an elevation of 3,920 feet, thus giving the elevation of the top



GENERAL MAP OF PROPOSED SAN PEDRO PROJECT, ARIZONA.

contour 4,020 feet. The capacity of the reservoir at this elevation is found to be 60,235 acre-feet, with a surface area of 2,247.3 acres. The areas for each contour will be shown in the following table:

Areas of San Pedro reservoir at different contours.

Contour.	Area.
Feet.	*Acres.*
3,920	0
3,930	43
3,940	17
3,950	66
3,960	177
3,970	367
3,980	579
3,990	881
4,000	1,212
4,010	1,597
4,020	2,247

The building of this dam would submerge about 6 miles of the El Paso and Southwestern Railroad, and necessitate the construction of 9.4 miles of new line. It would also submerge two mineral claims, about 100 acres of cultivated land under irrigation, about 480 acres of pasture land under fence, the Louis Springs railway station and water tank, a few worthless adobe houses belonging to Mexican section laborers, a small cyanide plant at work on an old pile of mill tailings, and about 7 miles of pipe line of the Huachuca Water Company. Only a rough guess can be given as to the value of the mines, since they are not working at present and are filled with water; they are owned by Charles Fisher, Fairbanks, Ariz. Their estimated value is not over $25,000. The cultivated land would cost about $50 per acre, or $5,000 in all, and the pasture land about $20 per acre, or $9,600 in all. The adobe huts are hardly worth anything and in a few years the cyanide plant will be through working the tailings and moved away.

The El Paso and Southwestern Railroad runs through the reservoir site along San Pedro River for a distance of nearly 6 miles, and in order to utilize the reservoir, the railroad will have to be moved. The estimated cost of the removal is as follows:

Estimate of cost of moving railroad line, San Pedro project.

Excavation:	
First mile, 39,910 cubic yards earth, at 15 cents	$5,986
Second mile—	
33,960 cubic yards earth, at 15 cents	5,094
5,790 cubic yards rock, at $1	5,790

Excavation—Continued.		
Third mile, 9,570 cubic yards, at 15 cents	$1,435	
Fourth mile, 23,370 cubic yards, at 15 cents	3,505	
Fifth mile, 12,600 cubic yards, at 15 cents	1,890	
Sixth mile, 10,560 cubic yards, at 15 cents	1,584	
Seventh mile, 5,300 cubic yards, at 15 cents	795	
Eighth mile, 7,460 cubic yards, at 15 cents	1,119	
Ninth mile, 20,020 cubic yards, at 15 cents	3,003	
Tenth mile, 2,670 cubic yards, at 15 cents	400	
		$31,603
Trestles, bridges, and culverts:		
First mile, 190 feet of trestle, at $5	950	
Third mile, 285 feet of trestle, at $5	1,425	
Fourth mile, 200 feet of trestle, at $6	1,200	
Fifth mile, 20 feet of trestle, at $4	80	
Sixth mile, 300 feet of trestle, at $6	1,800	
Truss bridge 150 feet long	10,000	
Culverts	2,400	
		17,855
Railroad track:		
49,495 feet, at $7,592 per mile		71,174
Incidentals		3,500
Total		124,132

The detailed estimate of the cost of the railroad track per mile is as follows:

Cost of a mile of standard-gauge railroad track.

110 tons steel rails (70 pounds per yard)	$3,850
710 angle bars, 20 pounds each	355
1,420 bolts, 7 kegs, 200 pounds each	56
5,670 pounds spikes, 38 kegs, 150 pounds each	171
2,640 ties	660
Ballast	2,100
Track laying	400
Total	7,592

If the old track and ties, etc., of the present location of the railroad could be used or arrangements made to have the railway company furnish the rails, etc., the cost of the road would be reduced.

DAM.

As there seemed to be several good locations for a dam in the gorge through which San Pedro River flows, just below Charleston, a map was made of it on a scale of 100 feet to 1 inch, with 5-foot contour intervals, and a site for a dam was chosen. At an alternate location, about 300 feet above the spot selected, the length of the dam near the bottom is smaller, but the sides of the gorge are not so steep and the length of the dam on top increases rapidly, with a small increase in height. For a smaller dam this would be the best location, but for a dam 120 feet high the proposed location seems to be the best for economy of material.

It was the original idea to make the dam 100 feet high, but a low gap in the mountains was afterwards found far to the west at an elevation of 3,935 feet, and in order to use this as a spillway in time of great floods it was thought best to increase the dam height to 120 feet, making the elevation of the top of the dam 3,940 feet. This, of course, provided that observations tend to show that the reservoir will be filled with à dam built to this height, since an increase of 15 or 20 feet in dam height will probably double the capacity. On recommendation of the board of engineers, computations were made for a rock-fill dam with one-fourth inch steel facing. The yardage was found for a rock-fill dam 120 feet high, 20 feet thick on top, with side slopes of 1 to 1 on each side. If, however, it was desired to make the dam with the same thickness on top, but with a slope on the upper side of ½ to 1 and a slope on lower side of 1½ to 1, it was found that the yardage of rock required would be the same, but in the latter case a smaller amount of steel would be needed. No borings were made to find the nature of the bottom of the stream, and so the estimate for excavation and foundations can be only a guess. The steel facing is to be embedded in concrete at the sides and bottom of the gorge to prevent percolation.

There is a good location for a spillway just west of the dam site if a heavy rock cut be made. As this rock could be used in the construction of the dam the additional expense would be small. The estimate is as follows:

Cost of dam, San Pedro project.

165,000 cubic yards rock, at $1	$165,000
450,000 pounds ¼-inch steel plate, at 10 cents	45,000
320 cubic yards concrete, at $6	1,920
500 feet tunnel, at $25	12,500
Gates and gatehouse	8,000
Excavation and foundation	30,000
Total	262,420

Summing the estimates, the total cost of the project is as follows:

Estimated total cost of San Pedro project.

Removal of railroad	$124,132
Construction of dam	262,420
Two mineral claims	50,000
100 acres of cultivated land, at $50 per acre	5,000
480 acres of pasture land, at $20	9,600
Incidentals	5,000
Total	456,152

CANAL.

Since it was found impossible to convey the water back on the mesa land, it was decided to allow it to flow from the reservoir as needed down the present river channel for a distance of about 9 miles from the reservoir or about 2 miles north of the town of Fairbanks, where the river banks are composed of a solid quartz-porphyry. Here the water is to be diverted by means of an over-fall masonry dam into the main canal, and conducted thus for a distance of 6½ miles before distribution commences. Both this conduit and the diverting weir are located wholly upon the San Juan de las Boquillas Nogales grant, the superintendent of which states that he is sure his company will have no objection to granting the right of way. After the water has been conducted in this first 6½ miles of canal it comes to the valley, which lies in a narrow strip between San Pedro River and a high bench or rough mesa land. The valley varies in width from 1 mile to 3½ miles; occasionally a long narrow strip of bench or mesa land will run out across the valley almost to the river, dividing the main valley into a number of small valleys. It would be useless to run the canal around these long strips of bench land, so that in most cases a tunnel or heavy cut is proposed. It has been the object of the assistant engineer in charge to keep just along the bottom of this bench at the upper side of the valley, thereby getting as much of the valley land under the canal as possible, at the same time locating the canal far enough away from the bench to avoid difficult and costly construction. It was found that a grade of 2 feet to the mile would best accomplish this result along the valley land and that a grade of 3½ feet would be needed on the first 6½ miles of canal.

The canal line was first run as a reconnaissance only, but under instructions from the consulting board, March 10, 1904, a careful survey of the first 6½ miles of line, which is through rough country, was made with a fall of 7 feet in one thousand. The line was platted in the field on plane-table sheets, using a scale of 100 feet to 1 inch (the adjacent topography being taken), and a paper location of the canal was made.

From this survey it was estimated that a canal with banks 7 feet high, with 5½ feet depth of water, delivering 250 second-feet, would have the following width on bottom and side slopes in the first 6½ miles:

In cut: Width on bottom, 8½ feet; side slopes, 1:1.
In part cut and fill: Width on bottom, 7 feet; side slopes, 1:1 and 1½:1.
In fill: Width on bottom, 6 feet; side slopes, 1½:1.
In rock: Width on bottom, 6 feet; side slopes, ½:1.

In the remaining 31¾ miles the canal would have a grade of 2 feet to the mile, a width on bottom of 12 feet, depth of water of 5½ feet, and side slopes of 1:1. The cost is estimated as follows:

Estimated cost of San Pedro canal.

First section, 6¼ miles:	
Excavation, 133,150 cubic yards earth, at 15 cents	$19,972.50
Excavation, 9,060 cubic yards rock, at $1	9,060.00
8 cut and cover culverts, 25 feet long, at $12 per foot	2,400.00
2 cut and cover culverts, 40 feet long, at $12 per foot	960.00
Second section, 31¾ miles:	
Excavation, 547,487.5 cubic yards earth, at 15 cents	82,123.00
24 cut and cover culverts, 25 feet long, at $12 per foot	7,200.00
6 cut and cover culverts, 60 feet long, at $12 per foot	4,320.00
1 tunnel, 280 feet long, at $25 per foot	7,000.00
1 tunnel, 260 feet long, at $25 per foot	6,500.00
Total	139,535.50

HEADWORKS.

As it is not known to what depth it will be necessary to go to find bed rock at the point of diversion of the canal line computations were made for founding the masonry weir on the gravel. By using wooden piles the weir can be erected at a minimum cost, and will probably be satisfactory in every way. For a foundation it is thought best that the heads of the piles should be covered with concrete and the masonry built on this; 3 feet of concrete should be sufficient.

It is proposed to make the weir of a maximum height of 20 feet, 15 feet wide at base and 8 feet wide at top, to be constructed of rubble masonry with a cut stone coping wall. On the upper slope is to be placed about a foot of concrete, faced with planking secured with long bolts; this can then be backed by earth filling with a slope of 1½ to 1. In order to prevent undermining it would be well to build a timber apron about 20 feet long on the lower side, with the lower end raised slightly so as to form a small water cushion. On the upper side the structure should be protected by sheet piling.

Taking the length of the weir as 160 feet, the cost would be as follows:

Cost of headworks for San Pedro canal.

Lumber, 58,000 feet, at $25 per M feet B. M	$14,500
Piling, 9,000 linear feet, at 60 cents	5,760
137 cubic yards cut stone masonry, at $12	1,644
356 cubic yards concrete, at $6	2,136
1,000 cubic yards earth in embankment, at 20 cents	200
120 bolts, at $3	360
Incidentals	5,000
Gates	5,000
Administration	5,000
Total	39,600

This would give a total cost for the whole canal as follows:

Total cost of San Pedro canal.

Headworks	$39,600
First 6½ miles	32,392
31¾ miles	107,143
Total cost of canal	179,135

SUMMARY.

The total cost of the project will be as follows:

Total cost of San Pedro project.

Dam and reservoir	$556,152
Canals and headworks	179,135
Total	735,287

As to the feasibility of the project little can be said until more data on the water supply are obtained. On account of the pass about a mile west of the dam, it is recommended that the dam be built 20 feet higher, increasing the capacity to 100,000 acre-feet. This would give water enough for 25,000 acres, which could be irrigated by the construction of about 5 additional miles of canal through good land.

With regard to construction, if the water supply amounts to 80,000 acre-feet, 20,000 acres of land can be irrigated at a cost of $36.77 per acre.

REPORT OF CONSULTING ENGINEERS.

The board of consulting engineers, consisting of H. N. Savage, W. H. Sanders, and George Y. Wisner, considered the report of Mr. Evans, and on May 29, 1904, reported as follows:

> The limited time during which measurements of the run-off from the storage basin above the proposed storage reservoir have been made renders an estimate of the dependable water supply largely an assumption.
>
> The increasing demand in Mexico for water incident to extensive and increasing mining operations should be carefully considered, since one-half or more of the drainage area of the San Pedro project is in Mexico. Also the rights of the Indians lower down on the Gila River should be considered before definitely determining the merits of this project.
>
> We are of the opinion that from 20 to 25 per cent should be added to the $36.77 cost per acre for the project as estimated by Mr. Evans.
>
> The good quality of the lands to be irrigated, and the demand for agricultural products, including vegetables and small fruits, in the vicinity of the project, and the limited area that can ever be brought under irrigation owing to the scarcity of water in this arid section, assures profitable returns on more than the average cost for the development of irrigation water.
>
> The success attending the development of water from artesian wells throughout a portion of the lands commanded by the proposed project will likely deter some of the private landowners from incurring the expense of the probable cost per acre for a stored gravity system.

We again recommend an investigation, of a preliminary reconnaissance nature, of the portion of the San Pedro drainage basin in Mexico, to determine the probability and possibility of storage and diversion therefrom in Mexico. We would suggest also an investigation to ascertain if the private landowners desire to subscribe to the project. We recommend the maintenance of a gaging station at Charleston, and that the San Pedro project be held in abeyance until the available water supply is more definitely determined.

NOTES ON THE UNDERGROUND WATER OF THE SAN PEDRO VALLEY, ARIZONA.[a]

During July, 1903, a brief examination was made of the artesian basin near Benson, Ariz. The majority of the settlers of that region have been in the valley but a short time, and land is being taken up for homesteads wherever water can be obtained. There is a strong sentiment in favor of admitting only such land seekers as will actually live upon the land taken up and become bona fide members of the community. The valley is situated in the midst of a mining region of considerable importance, and the demand for agricultural products far exceeds the possible supply. Nearly all produce is now shipped in from a distance, and high prices prevail. The development of water in this valley would, therefore, create a community of small landowners residing on their land, and at the same time materially benefit the important mining interests of the region.

The San Pedro Valley is situated between the Galiuro, Dragoon, Bisbee, and Tombstone mountains on the east, and the Huachuca, Whetstone, Rincon, and Santa Catalina mountains on the west. From these mountains many side streams enter the valley. Most of them sink beneath the surface before reaching the San Pedro, but a few reach that stream. The San Pedro has a continuous surface flow, although the volume is small during the dry seasons.

The valley was examined from Benson to a point about 8 miles south of Fairbanks, a distance of about 28 miles. This part of the valley is divided into two basins by a series of igneous buttes, which extend across the valley about 8 miles south of Fairbanks. South of the buttes the valley is said to be developed to very little extent. The major part of the settlement is north of or downstream from the buttes. From the buttes northward for about 10 miles the igneous rock appears in places at the surface, and the fragmentary material is coarse. About 3 miles north of Fairbanks, however, the valley broadens, the igneous rock disappears, and the fragmentary material becomes finer. From this point to Benson and beyond, the valley fill is predominently a dull-red clay to a depth of about 500 feet, beneath which is coarser material to about 900 feet, the depth of the deepest wells. It is in this region that the wells described beyond are situated.

The valley floor is composed of two distinct divisions—the alluvial bottom lands, bordered by bluffs 60 feet high, and the mesa lands, rising gently from the bluffs to the bordering hills. The bottom lands slope gently from the bluffs to the river, and are composed of fine silt and clay with little sand. The mesa lands are carved into "bad-land structure" near the bluffs, but back a short distance the surface is comparatively even.

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[a] From report by Willis T. Lee.

The material of the valley fill is unconsolidated sand, gravel, clay, and cement, the clay greatly predominating. The bluffs are generally capped with gravel beds several feet thick. Below the gravels are alternating layers of sand and clay, more or less cemented. In many places the clay contains gravel, which is irregularly distributed and varies in size, the largest pebbles being several inches in diameter. Where the bluffs were closely examined a band of white cement about 3 feet thick was found. The records of wells indicate that the materials to a depth of over 900 feet is similar to that seen in the bluffs.

In the San Pedro Valley, as in other parts of the Southwest, there have been several stages of erosion and accumulation. Considering only the material forming the present valley fill, it is evident that a broad, deep valley was excavated in the older rocks; then this valley was filled with sand and clay to the elevation represented by the mesa, and in these deposits was carved a secondary valley, which was small compared with the original valley. The secondary valley was then partially filled—the condition at the present time.

Wells.—There are over 200 wells in San Pedro Valley between Benson and Fairbanks, a distance of 20 miles. These are owned by about 45 men. The wells are all bored, and vary from 1½ to 4 inches in diameter (with the exception of the railroad well). Some are cased only a few feet and the best are cased to a depth of only about 400 feet.

Southern Pacific Railroad well.—In 1900 two 10-inch wells, 707 and 808 feet deep, were bored at Benson for the Southern Pacific Railroad Company. Water was struck at a depth of 500 feet and flowed at the rate of 42 gallons per minute. The flow was not increased by the additional depth. A satisfactory amount of water was obtained by pumping and the boring was discontinued.

The pumps discharge 4,700,000 gallons during each month, or an average of about 109 gallons per minute. When the pumps are not in operation, water flows slowly from the top of the wells. When working at the regular rate, the pumps lower the water to a depth of 80 feet below the surface. A careful log of the wells was kept by the engineer in charge and is given herewith:

Log of well at Southern Pacific Railroad station, Benson, Ariz.

	Feet.
Surface soil	10
Sand and gravel	110
Clay	480
Sand	9
Clay	3
Sand	8
Clay	6
Cemented sand	75
Gravel	6
Sand and clay	44
Cement	20
Sand and "flint rock"	37

Curtis well.—One of the southernmost wells of the region is that of J. N. Curtis. It is a 2-inch well, 470 feet deep and cased 250 feet. The log is as follows:

Log of J. N. Curtis's well.

	Feet.
Sandy clay	150
Cement	1
Quicksand	10
Cement, clay, and sand	140
Clay	50
Gravel, water-bearing	5
Alternating layers of sand and clay	110
Cement	1
Gravel, water-bearing (main flow)	3

Carr wells.—H. O. Carr's wells are about midway between the Curtis ranch and Benson. There are two 3-inch and two 4-inch wells. The deepest is 600 feet, and flows about 70 gallons per minute. The four wells irrigate 30 acres. The material penetrated is mainly clay, as shown in the accompanying log:

Log of H. O. Carr's well.

	Feet.
Sandy soil	70
Red clay	290
Sand	40
Alternating layers of sand, gravel, and cement, water-bearing near the base	200

A comparison of these logs indicates that near the upper edge of the basin, where the igneous hills cross the valley, the coarse material, sand and gravel, is more common nearer the center of the basin, and gives place, in large measure, to the clay. It is thought that the same relation obtains at the sides—that the gravel beds thin out entirely between the layers of clay, making the passage of the water difficult and giving rise to the slight head shown by the water. The depth of the wells varies from 150 to something more than 900 feet. The water-bearing horizons seem to be rather irregular. In some cases the sand stratum yielding the water is only 2 feet thick. In other cases the water comes from a gravel bed which has been penetrated 20 or 30 feet without reaching the bottom. The depth is also more variable than would result from the surface unevennesses.

A few of the wells selected to represent the general distribution were investigated with care. (See table below.) They are among the best wells in the valley. The greatest flow from a single well is about 80 gallons per minute. There are all gradations from this down to wells that do not flow at all. P. A. Lofgreen, who has inquired into this subject for the Water Users' Association of the valley, estimates that the average discharge of the flowing wells is about 10 gallons per minute.

The water is used for domestic purposes and for irrigation. The wells, often four or five within a few hundred feet, discharge into small adobe reservoirs until enough water has accumulated to give a good irrigation head. One man is irrigating 30 acres from four wells, another 30 acres from two wells. The clay soil holds the water readily, and experience shows that a flow of 3 gallons per minute is sufficient for one acre. The flow of a well is diminished by other wells sunk near it. Mr. Riggs found that his second well, sunk about 20 feet from the first, diminished the flow of the first 10 gallons per minute. A similar diminution of flow was reported in several instances.

Log of W. A. Riggs's well.

	Feet.
Soil, gravel, and bowlders	80
Clay	300
Quicksand	40
Clay	80
Gravel and bowlders, water-bearing	90

Tabulation of some of the representative wells near Benson, Ariz.

Name.	Location.			How put down.	Size.	Depth.	Amount of flow.	Amount of casing.	Remarks.
	T.	R.	S.						
					In.	*Feet.*	*Gal. per minute.*	*Feet.*	
H. W. Etz & Co.	17 S.	20 E.	3	Bored	3 4	780 820	35 60	450	
J. H. Hallen	17 S.	20 E.	4	do	3	920	30	......	
Southern Pacific Railroad.	Town.			do	10	707 808	42	500	Pumps 109 gallons per minute.
J. N. Curtis	18 S.	21 E.	33	do	2	470	15	250	
W. A. Riggs	18 S.	21 E.	27	do	3 4	590	70 80	250	Irrigates 30 acres.
H. O. Carr	18 S.	20 E.	1	do	3 4	600	[a] 70	400	Has 4 wells; irrigates 30 acres.

[a] Best one.

The first indication of artesian water in the San Pedro Valley is said to have been noted at the time of a severe earthquake which occurred in 1887. A long fissure is said to have been formed, from which water flowed for several hours. This led to the supposition that water existed under pressure beneath the surface of the valley, and boring soon afterward resulted in flowing wells. The existing wells are crude in construction. They are sunk by means of an auger attached to a gas pipe and turned by a rotary horsepower apparatus, or sometimes even by hand. The boring is done by the farmers themselves with machines improvised in some cases from worn-out mowing machines. The wells are cased only so far as casing can be driven with a maul. This leaves several hundred feet of the hole with nothing stronger than a wall of soft sandy clay to prevent filling. The machinery is usually too light to penetrate the gravel beds which are frequently encountered, and these usually determine the depth of the well. But in spite of crude methods, these people have succeeded to a somewhat astonishing degree in getting artesian water.

The quantity of water to be obtained from a well seems to be limited. Eighty gallons per minute is the maximum flow and 10 gallons an average flow. It seems to make little difference in the flow whether the pipe is large or small. Some of the 2-inch wells flow 75 gallons, while the two 10-inch wells of the railroad company together flow only 42 gallons. It should be born in mind in this connection, however, that water has been pumped from the railroad wells for the last two years at the rate of 109 gallons per minute. The water has very little head. Seventy-five pounds or less on a 2-inch well will stop the flow.

The quality of the water is excellent, and even if no greater supply is found there is a sufficient quantity for the domestic use of a greatly increased population. There are good indications, however, that a greater flow may be obtained from deeper wells. In a number of cases, a water-bearing bowlder stratum was encountered at the bottom of the wells. The light machinery is not adequate to deal with this kind of material, and when it is encountered boring has to be discontinued. In some cases reported, the auger was forced down a few feet among the bowlders, with the result that "the waters increased with every foot."

SUMMARY.

1. There are a large number of flowing wells in the San Pedro Valley and good indications that much better wells could be obtained if properly constructed.

2. The quantity of water thus far developed is limited. This may be due not altogether to small supply, but also to improper construction that allows water to escape into pervious layers above the water-bearing strata: to the fact that the wells penetrate but a short distance

into the water-bearing sands and gravels; and to the compactness of the sands, which causes the water to move slowly through them.

3. The flow is diminishing in many of the wells. This is probably due to their filling with sand, because of lack of casing. Some wells have been flowing steadily for more than ten years, with little or no diminution of flow.

4. Artesian water is now used considerably for irrigation and could probably be developed to a much greater degree. The basin, however, is of limited extent and no large volume for irrigation is to be expected.

BABACOMARI RESERVOIR SITE, ARIZONA.

The Babacomari reservoir site is situated on Babacomari Creek, Arizona, just east of the line separating Santa Cruz and Cochise counties, on what is known as the Babacomari claim, owned by the Green Cattle Company. The Southern Pacific Company's line between Benson and Nogales passes through the site and through the narrow gorge in which the dam would be situated. However, if the site should be considered more desirable for a reservoir than for a railroad right of way, the road could be transferred to the hills without serious engineering difficulties.

The hills on the north are composed chiefly of limestone, seemingly of a quality that would be satisfactory for purposes of construction, while those on the south of the railroad are covered with loose rock and dirt, the rock varying in size from a pebble to a cobblestone.

Only a small amount of water runs in the creek, but it enables the few ranchers to irrigate garden patches and small fields. A reservoir established here would furnish water to the flats adjacent to the Babacomari, in addition to a supply for the valley itself.

RECONNAISSANCE OF WILLIAMS, SANTA MARIA, AND BIG SANDY RIVERS, ARIZONA.[a]

WILLIAMS RIVER.

On Williams River, about 8 miles below the junction of the Santa Maria and Big Sandy, is a dam site and a reservoir site of large capacity. Southwest of this reservoir site is a large body of irrigable land, known as Cactus Plain. It has been stated that possibly this land could be irrigated from this reservoir site, on Williams River, but investigation shows this to be impracticable, since the lands are about 800 feet above the bed of the river at the reservoir site.

About 3 miles below this reservoir site are about 500 acres of irrigable land on the left bank of the river, known as Rogers's ranch. Three miles below Rogers's ranch are about 300 acres of irrigable land. From Rogers's ranch for a distance of 6 miles the channel is from 700 to 1,200 feet wide, and consists of sand and gravel. There is no water in this portion of the river. At the lower end of the above stretch of river the channel is intersected by a ledge of rock, which brings the water to the surface, so that probably 10 miner's inches flow over the ledge during low water. However, it again sinks into the sand a few hundred feet below the ledge, and disappears for a distance of 25 miles, when it reappears at the Planet mine.

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[a] From report by Jeremiah Ahern, April 20, 1903.

Between the ledge and the Planet mine the channel varies in width from 800 feet to 1½ miles, being confined in many places between almost vertical walls of rock and in others by steep, rocky slopes. There is no bottom land along this stretch with the exception of about 60 acres on the right bank, about one-half mile below the ledge. Water is taken from the river at the ledge and conveyed to the land by a ditch. All of the irrigable land is under cultivation.

There are a few short stretches of bottom land on the left bank just above the Planet mine, extending from the mine up the south bank of the river for a distance of about 2 miles with an average width of 1 mile. About one-fourth of the area of this land is covered with a thick coat of alkali. Probably the most economical method of irrigating here would be by pumping from the river one-half mile distant and about 30 feet below, there being no feasible way of getting water on the land by a gravity conduit. One-fourth mile below the mine water again comes to the surface and continues to Aughdak's ranch, 4 miles below the Planet mine, where it is all taken out in a ditch, irrigating about 160 acres. Between Planet mine and the Aughdak's ranch a Mexican takes water out in a ditch and irrigates about 40 acres. On Aughdak's ranch some grape vines and fruit trees were observed. One mile below the ranch the canyon widens to 1 mile, and during high stages the river occupies the entire channel.

Two miles below Aughdak's ranch water again comes to the surface and continues to Colorado River. Four miles below the ranch there are 60 acres of irrigable land. Three or four Indian families live here and bring water on the land by a ditch from the river, irrigating about 20 acres. Two miles farther down, and about 2 miles from Colorado River, a Mexican irrigates about 20 acres. Between Aughdak's ranch and Colorado River, for a distance of 1 mile, the canyon is about 1,000 feet wide, and for the remaining 7 miles it averages 1 mile, with a slope of probably 15 or 20 feet to the mile. The entire valley is occupied by water at high stages of the river. One thousand acres would cover all irrigable land between Aughdak's ranch and the Colorado.

SANTA MARIA RIVER.

About 18 miles above the junction of the Santa Maria and Big Sandy and about 1 mile above Clark's mill is a dam site. The canyon here is about 150 feet wide at the bottom, with sides sloping about 60 .

There is a very good reservoir site above this canyon. A dam 100 feet high would probably form a reservoir covering 1,500 to 2,000 acres, with an average depth of 30 feet, giving a capacity of from 15,000 to 20,000 acre-feet. It is probable that such a reservoir would be filled only once in four or five years, or even at longer intervals, since this is generally the interval between freshets.

The channel is dry above Clark's mill, there being a flow of 2 or 3 miner's inches at the mill, which sinks about 1 mile below. Four or 5 miles above Clark's mill another canyon begins, and, it is stated, continues for 6 or 7 miles, and has a reservoir site above it. This site was not examined.

The wagon road from Congress Junction to Santa Maria River ends at Clark's mill, but no difficulty is encountered in traveling with a wagon down the dry channel of the river, except over a few short stretches of bowlders. For a distance of 10 miles below Clark's mill the river is in a canyon from 400 to 1,000 feet wide. At Grapevine Springs, 12 miles below Clark's mill, the valley widens. Here it is 1 mile wide, and is covered with sand and bowlders. On the left bank at Grapevine Springs is a stream of water of 1 miner's inch issuing 20 feet above the ground from a vertical wall of sandstone about 60 feet high. A few acres adjacent to the spring are irrigated by a Mexican. Three miles below Grapevine Springs a Mexican has several fields fenced in and a ditch leading to them, but neither water nor crops were observed. About 1 mile above the mouth of the Santa Maria a few acres of alfalfa is raised, water being brought from the river in a ditch.

This includes all of the irrigated land on the river from the mouth of the canyon 5 miles above Clark's mill to the junction of the Santa Maria and Big Sandy—a distance of 23 miles. Between Grapevine Springs and the mouth of the Santa Maria there are in all probably 1,000 or 1,200 acres of irrigable land—too few to justify storage. Diversion from a reservoir site on the Santa Maria to mesa land on the south is impracticable.

BIG SANDY RIVER.

There is one irrigated ranch on the Big Sandy near its mouth. From this ranch to the old mining camp of Signal, a distance of 14 miles, the river is in a narrow valley, with mountains on each side. No land along this part of the river is fit for cultivation with the exception of a few acres, which some Mexicans have attempted to cultivate with but little success. At Signal, and for 2 or 3 miles above, the river channel averages three-fourths mile in width. Just below, the canyon is about 500 feet in width, passing between the ends of two ridges at right angles to the river. A dam 30 or 40 feet high could be constructed here, with spillways over the ridges, but there is no irrigable land on which the water could be used. At Signal it was learned that there has been no flood in the river for seven or eight years, and that it takes 5 inches of general rain to cause high water. For 8 miles, between Signal and the mouth of the river, the channel is dry, there being about 10 miner's inches flowing immediately below Signal.

Four miles above Signal there are about 50 acres of irrigable land. An attempt to irrigate this land by pumping with a gasoline engine from a hole in a side wash has been tried, but the water gave out and it proved a failure. Nine miles above Signal are two small ranches, one on each side of the river. Sixteen miles above Signal is William's ranch, where 40 acres are irrigated. For a distance of 9 miles above William's ranch nearly all the bottom land is cultivated, alfalfa, barley, and wheat being observed. The water comes to the surface just above this cultivated area, and there seems to be a sufficient quantity for irrigation. For a distance of 20 miles above the cultivated land, or until Trout Creek is reached, the river is entirely dry. There are several deserted farms along this portion of the river, and it is reported that up to four or five years ago there was an abundance of water for irrigation. The lack of water is attributed to a series of seven or eight dry years. On one of these deserted places there had been a large orchard.

Trout Creek enters the Big Sandy about 50 miles above Signal, with a flow of about 3 second-feet, which continues down the channel of the river for a mile. About 35 acres are irrigated at the mouth of the creek, and about 70 Hualapai Indians live along it and cultivate small patches of land. Twelve miles from its mouth there is a circular basin, three-fourths to 1 mile in diameter, of bench or mesa land 40 to 50 feet above the bed of the creek, the channel of which is about 500 feet wide. Between 5 and 6 second-feet of water were flowing here, but the place is not suited for either a dam or reservoir site. All of the water in Trout Creek comes from a single spring 24 miles above its mouth, the flow being almost constant. During the rainy season, in July and August, torrential freshets occur. There are quantities of drift 15 to 20 feet above the bed of the creek.

SUMMARY.

There are reservoir sites on Williams, Santa Maria, and Big Sandy rivers. The one on Williams River has a good dam site, with storage capacity probably large enough to hold all of the water that ever would come down the river during its greatest freshets, and it is evident from the positions of drift that at times this volume is very large; but, unfortunately, there is no irrigable land upon which to utilize it, except along the valley of Colorado River, where there is an abundance of water. The same objection applies, more or less, to the other two rivers.

IRRIGATION IN THE BASIN OF LITTLE COLORADO RIVER, ARIZONA.[a]

WATER SUPPLY.

Little Colorado River drains nearly 6,000 square miles of territory in northwestern New Mexico and more than 9,000 square miles in northeastern Arizona, making a total drainage area of 15,000 square miles tributary to the river above Winslow, Ariz. This drainage basin extends from the Mogollon Mountains on the south to the Salahkai Mesa on the north and eastward to the Continental Divide. A general map of the region tributary to Little Colorado River is shown on Pl. XI.

There are two flood seasons, the spring flood, due to the melting of snow on the mountain slopes, and the fall flood, resulting from the late summer rains.

The surface of most of this area is either red or blue clay on the lower slopes, and a solid sand or lava rock partly covered with sod, embracing 50 per cent of the mountain and foothill slopes. These surface conditions prevent the water from sinking into the ground and make all the streams torrential in their flow.

As no measurements of the flow of Little Colorado River or its tributaries have been made during the flood seasons, the amount of water available is entirely a matter of conjecture. That it is at times very great is shown by the large channels and heavy cuttings; also by the difficulty the Santa Fe Railway Company has had in securing its embankments. That it is very small during certain seasons is certain, for during the time these surveys were made, in January and February, 1904, it was entirely dry at Winslow and had less than 5 second-feet flow at Holbrook. Silver and Clear creeks, and Chevlon Fork, were its only tributaries which were not entirely dry, and the waters of the latter two were all diverted before reaching the river.

From these conditions it is very evident that any reliable system of irrigation must depend on reservoirs made not only to hold the spring waters for midsummer use, but to carry the surplus waters of a maximum year through a series of from three to five years to meet conditions similar to those which prevailed in the spring of 1904, when, owing to there being no snow in the mountains, there was no spring flood, and no water was therefore available until the fall rains, possibly too late to help the crops.

CULTIVATED LANDS.

At present only a small area of land is irrigated along Little Colorado River. At St. Johns, Concho, Snowflake, Taylor, and Showlow, on the slopes of the Mogollon Mountains, and at Woodruff, St. Joseph, and Winslow, on the main river, are tracts of from 1,000 to 3,000 acres farmed by irrigation.

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[a] From report of J. G. Camp.

At other places are scattered Mexican ranches consisting of a few acres of garden and meadow. Approximately 16,000 acres are irrigated at present, but a large part of these lack water through July and August. This difficulty has been partly met by small reservoirs, but faulty construction has caused the dams to break frequently, making the reservoirs expensive and of but little help.

IRRIGABLE LANDS.

In the valley of the Rio Puerco (the main tributary of the Little Colorado) are several fine bodies of land, but, there being no reservoir sites above them, these are not available unless the underflow could be pumped onto them. Water is found from 10 to 30 feet below the surface, but as to the amount available there are no data. Below the junction of the Rio Puerco and the Little Colorado rivers, beginning at Holbrook and extending westward along the latter stream, is a valley from 1 to 5 miles wide, part of which is fertile cultivable land. Below Winslow, Ariz., this valley widens to 8 miles, and has a fine sand-loam soil. It has easy slopes, unbroken by ridges and buttes. The total irrigable land is approximately 160,000 acres.

TRIBUTARIES OF THE LITTLE COLORADO.

ZUÑI RIVER.

Zuñi River drains a large area, but seldom contributes any water to the Little Colorado. After leaving the mountain slope it traverses a badlands country, where the water sinks into the sand. When, in years of maximum fall rains in the badlands, its flow reaches the main river, it carries so large a percentage of silt that it could not be used in a reservoir. It is used to a small extent for irrigation at Zuñi Reservation, and the agent is planning to divert the entire flow at that point.

The Little Colorado River above the mouth of the Zuñi has not sufficient flow to irrigate the lands under cultivation near St. Johns and Concho, though in the last two years their reservoirs have stored all the flood waters. So, although a very good reservoir site was found at the junction of the two rivers, it is considered impracticable for lack of water.

COTTONWOOD WASH.

Cottonwood Wash, which empties into the Little Colorado 5 miles above Winslow, drains a large area of badlands north of the river. During the fall rains it is often a fair-sized stream, but carries so much silt that its water could not be used in a reservoir, and its flow is so short and uncertain that it could not be depended on. There is some underflow there that might be pumped, if fuel were obtainable at reasonable rates.

SILVER CREEK.

Silver Creek has a drainage area of 1,044 square miles, a large portion of which is on the slopes of the Mogollon Mountains, where, in ordinary years, there is a snowfall which supplies the spring flood. Since most of these slopes are of solid basalt or sand rock, but little silt comes down with the spring floods. The fall rains bring some silt from the low hills, but a large portion of the lower country is rock capped.

At Snowflake and Taylor are three small reservoirs in operation, and one in process of construction. As owing to faulty construction these dams are carried away nearly every spring, it is hard to estimate how much water they have stored—probably not more than 6,000 acre-feet. Between 3,000 and 4,000 acres are cultivated by irrigation in the vicinity of Snowflake. Twelve miles above this town is a fine little reservoir site which private enterprise contemplates using to store water for irrigation of additional land near Snowflake. The valley at Snowflake would make a good large reservoir, as it narrows to a box canyon 2 miles below the town, but it would submerge the town and 3,000 acres of cultivated land, and as there are equally good sites lower down at the Forks and at Woodruff, this site was not surveyed.

RIO PUERCO.

The Rio Puerco is the largest tributary of the Little Colorado and drains an area of 2,400 square miles. A portion of this area is on the slopes of the Continental Divide and is always sure of snowfall. The stream is over 100 miles long, but its lower channel is very sandy, causing a large loss of water. The Santa Fe and Pacific Railroad follows this stream the full length and would interfere seriously with reservoir building had there been any sites on the main stream. In any event the large amount of silt would make any reservoir on the main stream impracticable. However, the stream can be diverted into the Le Roux Wash, where there is a good reservoir site.

LE ROUX WASH.

Le Roux Wash is a long stream, draining the country west of the Rio Puerco. Its drainage area is 2,124 square miles, but this, though large, is all of low hills and badlands, and depends on the rains for its run-off. In consequence of this and of a long sandy channel it can not be relied on to deliver any large amount of water at the reservoir site.

SOIL.

The soil on the south side of the main river between Holbrook and the mouth of Chevlon Fork is largely a red adobe clay, this being the soil in the broad draws and along the river bottom. On the steeper slopes is a sandy loam. On the north side a few small tracts of adobe occur, but the soil is mostly a fine sandy loam. In places this is loose and drifts, but where it has been leveled and kept wet it has made the best of soil. The red adobe raises fair crops, but is hard to cultivate, it being necessary to work it at just the right stage of moisture. Where this soil has not sufficient drainage it quickly becomes too strong with alkali to be fertile.

CLIMATE.

In this region the winters are not very severe. Snow seldom remains on the ground at Woodruff. The lowest temperature is about 12° below zero, and cold weather is over by the last of February. March is windy, but warm enough to start grass. With April the spring rains commence, and last some seasons until June 1. The summer season is hot and dry. The fall rains begin in August or early September.

CROPS.

Originally this section was a fine grass country, supporting large herds of cattle, but excessive pasturing of sheep and several dry seasons has nearly ruined it as a grazing country, at least in the portions convenient to water.

Alfalfa is the principal crop. It produces from 2 to 3 tons to the acre during the season, being cut three times. This seems a very low yield, and it is possibly due to the scanty water supply during the summer months. With plenty of water the sandy soil should give a yield of 5 tons per acre during the season. Sorghum and corn produce well, either as a forage or for the molasses and grain. Barley and wheat give fair yields. Irish potatoes are a failure in the valley below Holbrook, but sweet potatoes should do well in the sandy soil. Gardens do well, and sugar beets grown at Winslow gave under tests 18 per cent of sugar. Fruit trees grow finely in all portions, but a late frost in the spring often kills the fruit.

MARKET.

The main crops will always be forage, as the country, owing to its mild winters, makes a fine feeding country for cattle and sheep. The increasing damage to the outside ranges is making it more necessary every year that the beef and mutton shall be fattened on cultivated feed. As this country is traversed by the railroad, it will be a great feeding section and will use all the forage that can be raised. There will be a limited demand for vegetables along the railroad. With an abundant and certain water supply a beet-sugar factory should pay well.

RESERVOIR SITES.

WOODRUFF RESERVOIR.

This reservoir site is situated on the Little Colorado, 2½ miles below the mouth of Silver Creek. It consists of two basins, through which the river flows. The lower basin closes into a box canyon composed of almost vertical walls of soft sandstone about 100 feet high and from 300 to 400 feet apart.

A survey was made with the idea of constructing a dam 105 feet in elevation from the bottom of the river bed. The following table gives the capacities at the different contours:

Capacity of Woodruff, Ariz., reservoir at different contours.

Contour.	Area.	Capacity of section.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
5	6	6	....
10	20	64	70
15	31	128	198
20	44	188	385
25	46	244	629
30	71	293	921
35	128	497	1,418
40	324	1,128	2,546
45	581	2,261	4,807
50	810	3,466	8,274
55	571	4,204	12,478
60	937	4,522	17,004
65	1,056	4,984	21,984
70	1,715	6,930	28,913
75	1,936	9,680	38,593
80	2,470	11,567	50,160
85	2,668	12,845	63,004
90	2,784	13,631	76,635
95	3,031	14,538	91,173
100	3,158	15,471	108,644

It will be noticed that up to the 50-foot contour the capacity is very small. This is due to the fact that a deep wash extends through the lower basin, leaving the floor of the basin practically 40 feet above the level of the river bed at the dam site.

The location for the dam is very favorable for a rock-fill dam, as there is abundant rock both up and down the canyon. A cableway would deposit it cheaply. It would have to be quarried, but would work easily. The unknown factor is the depth of sandy sediment i the bottom of the canyon; the canyon walls apparently descend almo vertically, and three-fourths of a mile above bed rock appears in th river bed. The location for the wasteway is excellent; it will be c solid rock, in one direction reaching the canyon wall 600 feet belo the dam, and in the other 1,500 feet below. It could easily be excavate 400 feet wide and the rock transferred to the dam so that the spillwa would cost practically nothing.

This reservoir would flood 1,000 acres of cultivated land in th upper basin near the town of Woodruff.

FORKS RESERVOIR.

Since it is not desirable to destroy a prosperous community, as wou be necessary with the Woodruff reservoir, a location commencing mile above was also surveyed. This site will submerge no cultivate or deeded land, a freight road, which could be easily shifted, being th only property damaged.

The following table gives the capacities at different contours:

Capacity of the Forks reservoir, Arizona, at different contours.

Contour.	Area.	Capacity of section.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
5	90	121	121
10	106	489	610
15	120	566	1,176
20	166	717	1,895
25	250	1,041	2,935
30	277	1,321	4,256
35	316	1,482	5,737
40	594	2,275	8,012
45	985	3,947	11,959
50	1,275	5,649	17,607
55	1,312	6,317	23,924
60	2,374	9,215	33,139
65	2,997	13,428	46,567
70	3,651	16,620	83,187
75	4,131	19,455	102,642
80	4,482	21,558	124,200
85	5,015	23,743	147,943

This site includes about 4 miles of box canyon on Silver Creek ar an equal amount on the river.

A less costly dam could have been built on the river above the mout of Silver Creek, but as the water supply will come mainly from that creek it is necessary to put it below. Between the forks and the dam site there is but 10 feet fall, while no good site occurs for a high dam with good wasteway.

The dam site is very similar to that of the Woodruff reservoir, with the strong possibility of its being deeper to bed rock, as one-half mile below a diversion dam built by the ranchers of Woodruff has filled up 20 feet in depth with sediment and sand, making a dead level to this dam site. Here, also, a rock-filled dam with a cement core would seem advisable, although if bed rock were found near the surface and the sand rock were strong enough to stand in a high dam a masonry dam might be advisable.

The outlet could be a tunnel in either wall of the canyon. On the north side is a fine location for a wasteway on a nearly level solid rock bench. In one direction 750 feet cut would drop the water into the canyon and in another, slightly different, a few thousand yards of excavation would drop it into the head of a rocky gulch leading to the canyon 1,500 feet below the dam. The rock excavated on either route could easily be put into the dam.

The floor of this reservoir is sandy loam in the upper part, but the river channel shows that it is underlain with a clay hardpan and in places with rock. Below the forks the floor of the basin on the bench along the canyon is sand rock. As this rock formation seems to be deep and extends across country, there should be little loss from seepage after the basin is once soaked full.

As it is not at all probable that the drainage area would furnish water for both the forks and the Woodruff reservoirs, the former can well take the place of the other and avoid the necessity of destroying the property of the citizens of Woodruff.

LE ROUX RESERVOIR, ARIZONA.

This site is 4 miles northwest of Holbrook and 3 miles from the mouth of Le Roux Wash, and is designed to store the waters of the Rio Puerco, which can be brought in by a feeder ditch, and the waters of the wash. It is a very regular oval basin. The larger part of the floor is black adobe clay, which appears to underlie even the loose sand on the east side of the basin and crops out in the bluffs on both sides of the dam. These bluffs are capped with a ledge of soft sand rock from 10 to 25 feet thick, underlain by a hard clay that in places is almost rock. At the dam site the rock strata pitch downward underneath the black adobe clay of the basin. It is apparently the same ledge on both sides and probably could be reached at no great depth under the sandy soil that composes the floor. It is 1,900 feet between these bluffs, but this was the only available place for a dam.

As the water line will be only 35 feet above the floor an earth dam will be sufficiently strong here. One mile above the site black clay can be easily obtained. With this a puddled center core can be built up that will effectually stop all seepage.

At the south end of the dam is an almost level bench on top of the bluff, here about 40 feet high, with a rock cap 25 feet thick. With but small expense in building a guiding wall 300 feet long and in excavating 9,000 cubic yards of soil and rock this would make a good wasteway. If much water passed over it, it might be necessary to rip-rap at the base of the cliff to prevent undermining. The wave action will be very heavy and will necessitate facing the upslope. There being plenty of flat rock in the vicinity, this could be done by laying them shingle fashion.

The following table gives the capacities of this reservoir at different contours:

Capacity of the Le Roux reservoir, Arizona, at different contours.

Contour.	Area.	Capacity of section.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
4	8	16	....
5	34	21	37
10	105	346	383
15	1,032	2,842	3,225
20	1,836	7,169	10,393
25	2,236	10,178	20,571
30	3,164	13,501	34,072
35	3,726	17,267	54,298

TUCKER FLAT RESERVOIR.

This reservoir site is about 5 miles northwest from Winslow, Ariz., at a spot where Tucker Wash widens out into a flat, which at times is a shallow lake. It is oval, with abrupt shore lines and very level floor of red adobe clay, making a perfect bottom which prevents seepage. The dam will be rather long, but the spot is deemed the best available. The basin continues almost level for 2 miles below, to a place where there is a possible dam site, but it would not permit more than a 30-foot shore line and had no good location for wasteway. The latter is very essential, as the Tucker Wash is long and drains an area subject to waterspouts.

The following table shows the capacities of this reservoir at the different contours:

Capacities of Tucker Wash reservoir, Arizona, at different contours.

Contour.	Area.	Capacity of section.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
5	985	2,463	2,463
10	1,393	5,945	8,408
15	1,766	7,896	16,305
20	2,212	9,945	26,250
25	2,472	11,709	37,959
30	2,815	13,216	51,175
35	3,070	14,714	65,889
40	3,304	15,937	81,826
45	3,570	17,186	99,012
50	3,848	18,545	117,567

There being abundant material convenient, a combination rock fill and earth puddle would probably be the cheapest and could be made entirely safe.

The bottom of the dam site is red adobe clay; on this a rock-fill dam with 2 to 1 slopes could be constructed first. The upper face could be finished with small rubble and against this a section 20 feet in width of the adobe clay could be built up and puddled, forming an effectual barrier to seepage. The top of this slope would need to be riprapped, as the wave action would be very heavy for several months in the spring.

The bluffs on both sides are capped with a ledge of soft sandstone from 20 to 30 feet thick, beneath which is very hard clay. Rock for the dam could be obtained from both bluffs, where there are large quantities that would not need to be quarried. The bluff on the west side being higher than the dam a cable carrier could transport rock even to the top of the dam with a downhill haul.

A wide, flat, rock-topped point on the east side presents all that could be desired as a wasteway to discharge the surplus into the draw a mile below the dam. The outlet could be placed under the center of the dam.

CANAL LINES.

LE ROUX FEEDER CANAL.

The Rio Puerco is the largest tributary of the Little Colorado but has no available reservoir sites. Nearly parallel to this stream on the west is the Le Roux Wash. A reservoir site was found near its mouth but the natural flow would not supply it. Between these streams is a broad divide; 5 miles above the reservoir site this is cut by a broad gap having an elevation of 144 feet above the water line of the reservoir. South of this gap the ridge rises several hundred feet and extends 7 miles southward to the edge of the Little Colorado Valley where it ends in a rock bluff.

The pass being so much higher than the water line, a line was run around the point of this ridge to see if a shorter practical route could be found between the two streams, but was abandoned, for after a few miles it lay on the face of an almost vertical rock and clay bluff, so irregular that the cost of construction would be prohibitive.

Starting at the gap mentioned, a preliminary canal line was run with a 0.15 to 1,000 grade to Adamana, approximately 21¾ miles distant, where it would intersect the Rio Puerco. From the gap several routes could be used to drop the water into the bed of Le Roux Wash, but a half-mile additional ditch would turn it into a steep draw. This would avoid broad sandy draws where the water would wash, adding to the amount of silt carried.

Two shallow lake beds on the summit of the gap could be used as settling ponds. The right of way is all on Government land, except the last 2 miles at Adamana. The larger part of the construction would be in a sandy soil with some wash gravel. The canal would have a capacity of 2,100 second-feet.

NORTH SIDE DISTRIBUTING CANAL.

This canal line, with its initial point at the outlet of Le Roux reservoir, was run as a control line for the irrigable land on the north side of Little Colorado River. It was not held up to a grade, but when steep slopes or rock increased the cost of construction beyond the amount justified by the value of the higher lands it was dropped.

It would be 37 miles long to the crossing of Cottonwood Wash, to which point it would control 21,000 acres. One thousand acres are now irrigated by the St. Joseph canal, leaving 20,000 acres unprovided for.

A canal 25 feet on the bottom, 36 feet on top, 5.5 feet deep, with 0.2 to 1,000 grade, would carry 380 second-feet of water.

The Le Roux reservoir, with its capacity of 54,000 acre-feet, would not be sufficient to irrigate this 20,000 acres, but a canal 3½ miles long diverting from Little Colorado River above Holbrook could bring a portion of the water stored at the Forks reservoir down to this site, and at the same time aid in irrigating about 1,200 acres on the north side of the river, between Holbrook and Le Roux Wash.

SOUTH SIDE DISTRIBUTING CANAL.

The waters stored near Woodruff would follow the natural channel of the river to a point known as the Scores dam, situated at the mouth of the box canyon a mile above the junction of Rio Puerco and the main river. This would make a good place for diversion dam, there being solid rock on both sides and probability of rock beneath the stream bed at no great depth.

After the first 3 miles the ditch would be on easy dirt slopes. The line was surveyed to a point south of Apache Butte, where it had elevation sufficient to pass over the divide back of the butte and control all the land to the mouth of Chevlon Fork. From Holbrook to Chevlon Fork on the south side of the river there is a tract containing 28,800 acres of irrigable lands. From Chevlon Fork to Clear Creek the rocky mesa crowds close to the river, leaving but a narrow valley, which, however, widens out at Winslow, and contains 10,000 acres of irrigable lands above the outlet of the Tucker Flat reservoir. This tract could be irrigated from the Tucker Flat feeder canal with water from the end of the south side distributing canal.

These two tracts, amounting to 38,800 acres, and the 1,200 acres below Holbrook on the north side will be all that could be handled with the waters stored at the Forks reservoir.

The south side distributing canal would be approximately 28 miles long and would need a capacity of 620 second-feet. A canal 25 feet wide on the bottom, 7½ feet deep, and 40 feet wide on top would safely carry this. It could taper as it passed the bulk of the land.

FEEDER CANAL FOR TUCKER FLAT RESERVOIR.

The initial point of this canal is at the junction of Chevlon Fork and the river. It is designed to carry the waters of Chevlon Fork, Clear Creek, and Jacks Canyon into the Tucker Flat reservoir. It could also divert any water that might be available in the river at its initial point; but unless it was free from silt this would not be desirable, as there is no silt to contend with in the other two streams. The diversion dam at Chevlon would present no difficulties.

On the line surveyed it would be necessary to build a rock dam 161 feet long and 60 feet high to divert the water of Clear Creek, as the line crosses the outlet of a box canyon up which it would not be practical to run a canal line. A dam here would necessitate the raising of the Santa Fe Railway Company's pump (which is 2 miles above this point) 20 feet. As the railroad company would have that much less elevation to pump, no objections should be made to this alteration. Considerable rock is encountered along the course until Jacks Canyon is passed. The waters from this canyon could be diverted with no expense except for wasteway.

This canal line aimed to enter the reservoir at a gap 2 miles above the dam. There is a gap near the dam with 43 feet less elevation, but a line from it would encounter heavy rock work, would traverse a portion of the town of Winslow, and probably cross the railroad three times, costing considerable for right of way.

The line surveyed was run along the highest practicable route. If the water supply is sufficient to make the reservoir practicable, a line at a lower elevation may be found more feasible.

The uncertainty as to the duration or size of the floods in the feeder streams makes estimates of the capacity of the canal equally uncertain. Assuming that the flood season will last three months, a canal 25 feet wide on the bottom, 39 feet wide at water surface, and 7 feet deep, with a fall of 1 foot in 5,000, would carry 560 second-feet of water and fill the reservoir in that time.

OUTLET CANAL OF TUCKER FLAT RESERVOIR.

Two lines were surveyed, one 7.2 miles long, following the river, and the other a cut-off that shortened the first line to 3.7 miles and placed it out of reach of the river floods. The construction will all be on comparatively level country, the lower part in a sandy and the upper part in red-clay soil.

Assuming 4 acre-feet as the duty of water for this section, the reservoir could handle about 28,000 acres. A canal 30 feet wide on the bottom, 46 feet wide on top, 8 feet deep, with a fall of 1 foot in 5,000, would carry 880 second-feet of water.

CONTINUATION OF NORTH SIDE DISTRIBUTING CANAL.

If storage facilities above Tucker Flat are sufficient to supply more water than will be needed on lands under the south distributing canal and under the north side distributing canal to Cottonwood Wash, the latter canal could be enlarged and extended 51 miles farther down the river, controlling 35,000 acres that can not be reached from the Tucker Flat reservoir.

SUMMARY.

Storage capacity for 428,440 acre-feet can be obtained.

There are 161,000 acres of agricultural land so situated that it can be irrigated from this system.

Under irrigation this land will produce profitable crops, for which there is a market; but it is not possible to determine how many acres can be irrigated and at what cost, owing to four unknown factors: (1) water supply, (2) amount of silt in flood waters, (3) duty of water, and (4) evaporation.

(1) There are absolutely no data in regard to the water flow of the river or its tributaries. No measurements have been made previous to these surveys, and the winter and spring of 1904 were so dry that there was practically no water to measure. The main river at Hol-

brook on February 14 carried 4.28 second-feet; at Winslow on March 12 it was entirely dry. At the latter date Chevlon Fork had a flow of 4.7 second-feet, and Clear Creek 6.4 second-feet. Judging by the stream channels there must at some time have been large volumes of water running in them, but whether for a few hours from a cloud-burst, a few days from heavy rains, or for a longer period is uncertain. Estimates by the residents who have had no experience in judging volumes of water, and who tell the most contradictory stories about duration of floods, are of no value. There is no doubt that at times there has been 3,000 second-feet, and possibly more, passing under the Holbrook Bridge, but in a country where cloud-bursts are common this is no guide.

(2) If the Le Roux Wash and Rio Puerco carry even 50 per cent of the amount of silt that the residents claim, it would be useless to impound their waters, for, in spite of all the possible precautions, in ten years or less the reservoirs would be full. The same would be true of the Little Colorado above Woodruff. The silt problem will not enter into the Tucker Flat project unless water be taken from the Little Colorado, for the other streams are practically clear.

(3) Inquiry among the irrigators in the sections now irrigated give estimates of duty of water varying from 1 acre-foot to 4 acre-feet. The higher duty is along the mountain slopes and the lower at Winslow. It also varies from season to season. During some years the spring rains last until June 1, and the fall rains commence August 20, making a very short irrigation season. In other years there are practically no spring rains, and the fall rains are late, giving double length of season. The fact that there are few, if any, accurate measuring weirs on the ditches raises a doubt whether the owners know how much they do use.

(4) In a country noted for much wind, as well as long, hot seasons, evaporation is certain to be large. The certainty that the stored water will need to be carried at times through several years makes it very essential that at least an approximate estimate of rate of evaporation be obtained.

At present it seems improbable that the available water supply will meet the requirements of a system covering more than one-half of the land available, or 80,000 acres. It would therefore seem advisable to concentrate the work where the largest body of the best land can be obtained. The land on both sides of the Little Colorado between Cottonwood Wash and Canyon Diablo is a sandy loam free from alkali, forming a large, compact body of level land easily irrigated.

A practicable plan for the irrigation of this tract would be to eliminate the Woodruff reservoir project and utilize the Forks reservoir site, which is of sufficient capacity to store all the water of the Little Colorado and of Silver Creek. By this plan the Le Roux site would be abandoned as impracticable, owing to the length of the feeder canal and the excessive amount of silt. The upper north-side and south-side distributing canals would also be omitted.

At a point about 2 miles below the mouth of Chevlon Fork a dam would be constructed to divert the water from the Forks reservoir, and the flow of Chevlon Fork and the river on either side. On the north side such a diversion could be made on the line of the Tucker Flat feeder ditch, or as much as 20 feet lower down. This would take the water from the river, Clear Creek, and Jacks Canyon into the Tucker Flat reservoir. This ditch should have sufficient fall to cleanse itself. When it reaches the gap at the east edge of Tucker Flat basin, it will be 50 feet above water level and, instead of being turned directly in, could be carried along the easy west slope of the ridge to a point opposite the wasteway. When the water was clear of silt and was needed in the reservoir it could be taken in at the gap, and when heavy with silt the upper portion of the flow could be turned into the reservoir, and the lower portion, carrying the silt, could be taken past the dam and turned into the outlet canal. In the irrigating season the full head could be carried past the reservoir. The large flat just below the reservoir would make an excellent settling basin. The construction of the outlet canal and distributing system would present no difficulty. In case sufficient land could not be obtained on the south side, a north-side line diverting below Chevlon Fork could cover the land on the north side, where probably 30,000 acres of good land could be covered.

NOTES ON THE UNDERGROUND WATERS NEAR TUCSON, ARIZ.[a]

Several days were spent in the vicinity of Tucson, investigating the possibilities of developing water for irrigation purposes. This investigation consisted in examining, first, the natural flow of streams, and, second, the underflow.

Comparatively little attention is paid to agriculture in the vicinity of Tucson. The local production is said to satisfy but a small part of the demand for such articles as are commonly supplied by farm and garden. At present a ready market is found for everything raised. There is an abundance of fine agricultural land, a demand for agricultural products at good prices, and a small body of landowners who seem to be willing to comply with all reasonable requirements in order to obtain an increased water supply.

There is very little surface water except in times of flood. The Santa Cruz has no definite continuous channel in this region and no regular surface flow; it is a lost river in the sense that the stream which exists in the upper reaches of the river disappears from the surface to make the underflow. The water obtained for irrigation at present is that which seeps into low places or enters the valley from springs at the base of the hills. The branch streams entering the valley from the neighboring mountains have, so far as noted, well-defined courses until they reach the bottom lands, where the channels disappear and the waters enter the valley fill. Here, as elsewhere in southern Arizona, are numerous isolated mountain masses and single peaks separated by wide reaches of gently sloping prairie land. The prairie land is composed of "river fill" and "wash" from the hills. Along the stream courses there is usually a strip of alluvial land, but toward the hills the surface becomes gradually steeper and more corrugated, while the material becomes coarser and more angular.

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[a] From report by Willis T. Lee.

The "fill" at Tucson is at least several hundred feet deep. The deepest well now in operation is 426 feet deep, and does not touch bed rock. The accompanying log of the well belonging to the Ice and Cold Storage Company indicates the character of the deposits at Tucson:

Log of well at the Ice and Cold Storage Company's plant, Tucson, Ariz.

	Feet.
Sandy soil	20
White cement	3
Sandy soil	2
Sand	10
Red clay	3
Sand and bowlders (water hard and bad)	30
Red clay	10
Sand (water-bearing)	3
Gravel and sand cemented with white caliche	20
Sand with water	5
Red clay	30
"Pudding" rock	15
Red clay	6
Sand with water	7
Cemented granite wash	3
Red clay and bowlders (8 inches maximum size)	30
White clay	10
Sand with water (arose to 40 feet 2 inches of surface)	3
Red clay and bowlders	75
White clay	5
"Pudding" stone	8
Red clay, no bowlders	20
Loose dry sand	3
Red clay, few bowlders	28

The streams in this vicinity, as in southern Arizona generally, are aggrading streams. The waters entering the valley from the hills soon sink, and are lost in the loose sands and gravels of the lower lands. Only the largest floods move for any great distance on the surface, and these are said to move as "sheet washes," except as local conditions cause them to excavate channels. This is well illustrated near Tucson. In former years the Santa Cruz had no definite course near Tucson, as it has at present. Floods moved slowly over a wide area of bottom lands until a few years ago, when an irrigation ditch is said to have started a channel, which is now several miles in length and has a depth of 15 feet.

There have been some efforts to save and utilize the flood waters, and considerable time and money have been expended in surveys. Mr. Roskrage (an engineer living at Tucson) has spent much time in surveying proposed reservoir sites and canal lines, but has arrived at the conclusion that the depth of the "river fill" along the Santa Cruz virtually prohibits the construction of a dam near Tucson adequate for the control of the flood waters of the river. There are certain localities, however, farther up the river, which may prove favorable as reservoir sites. It is evident, therefore, that the ground waters must be looked to for an immediate increase in the water supply.

GROUND WATERS.

There is a possibility that artesian water may be obtained in the Santa Cruz Valley, and the occurrence of flowing wells in San Pedro Valley, near Benson, strengthens this possibility. No tests, however, have been made.

The waters that are found in the surface gravels and constitute the underflow are abundant, and might be developed with profit to much greater extent than at present. Two methods are employed for obtaining the ground water—seeepage ditches and pumping plants.

SEEPAGE DITCHES.

Seepage waters are being utilized to some extent in the Santa Cruz Valley. The Allison ditch heads into a low place near Allison Hill, west of Tucson, where the floods have cut a channel beneath the water table. The seepage is increased to some extent by sinking perforated pipes, which aid in gathering the water.

The Rillito canal, northeast of Tucson, is said to obtain seepage water by the aid of a concrete flume submerged in the bed of Rillito Creek. Several other small ditches along the Rillito take out seepage water by means of open cuts to the extent of a few hundred miners' inches. The localities, however, where seepage ditches are possible are few.

PUMPING PLANTS.

There are a few pumping plants in the vicinity of Tucson which obtain a considerable supply of water, as indicated in the accompanying table. Two of the wells were drilled and obtain water from a considerable depth; the others draw from the surface waters, and except in the case of the city waterworks and the railroad wells, the wells and pumping apparatus are not such as to give the best results. Study of wells in the Salt River Valley indicates that the underground waters in the vicinity of Tucson could be developed with profit to a considerable extent by pumping.

The amount of lowering caused by the pumps, as shown in the table, seems to be due not so much to a limited supply as to imperfections in the construction of the wells. In general, the open wells are not deep owing to the difficulty encountered in the water-bearing gravels. The result is a seepage area too small for the pumps employed. The water table fluctuates to a considerable extent, there being an annual variation of 2 feet and a cyclic variation of 12 feet or more.

Tabulated records of the more important wells at Tucson, Ariz.

Name.	Location.			Size.	Depth.	Depth to water.	Amount of lowering by pump.	Kind of pump.	Kind of engine.	Gallons per hour.	Use.	Remarks.
	T.	R.	S.									
					Feet.	*Feet.*	*Feet.*			*Amount.*		
City waterworks	14 S.	13	13	4 feet	36	20	12	Plunge	Steam	83,333	City	
Wm. Pearce	14	13	26	8 by 22 feet	26	8	16	Centrifugal	do	40,500	Irrigation	25 acres irrigated.
Wm. Tonpkin	14	13	35	8 by 12 feet	37	16	15	do	do	48,000	do	70 acres irrigated.
G. E. Kohler	14	13	26	8 by 8 feet	30	11		do	Gasoline		do	Not complete.
Southern Pacific R. R.	14	13	2	12 by 24 feet	41	29	8		Steam	14,333	Railroad use	
Southern Pacific R. R.	14	13	12	12 by 15 feet	51	33				14,000	do	Do.
University of Arizona Territory.	14	14	7	8 by 10 feet	108	85	16+	Plunge	Steam	10,000	Irrigation and school.	Small yard and garden watered.
Electric Light and Power Co.	City.			7 inches	426	40		do	do	1,050	Factory	Water taken only at 326 feet.
Ice and Cold Storage Co	City.			6 inches	349	36	14	do	do	18,000	do	Pipe not perforated.
R. Garstang	13	14	29	4 by 4 feet	50	45	2	do	Gasoline	1,000	Irrigation	Lawn and garden.
C. O. Crane	13	13	26	4 by 6 feet	53	51	22	do	Steam	16,000	do	Incomplete, 9 acres now irrigated.

OPERATIONS IN CALIFORNIA.

By J. B. Lippincott.

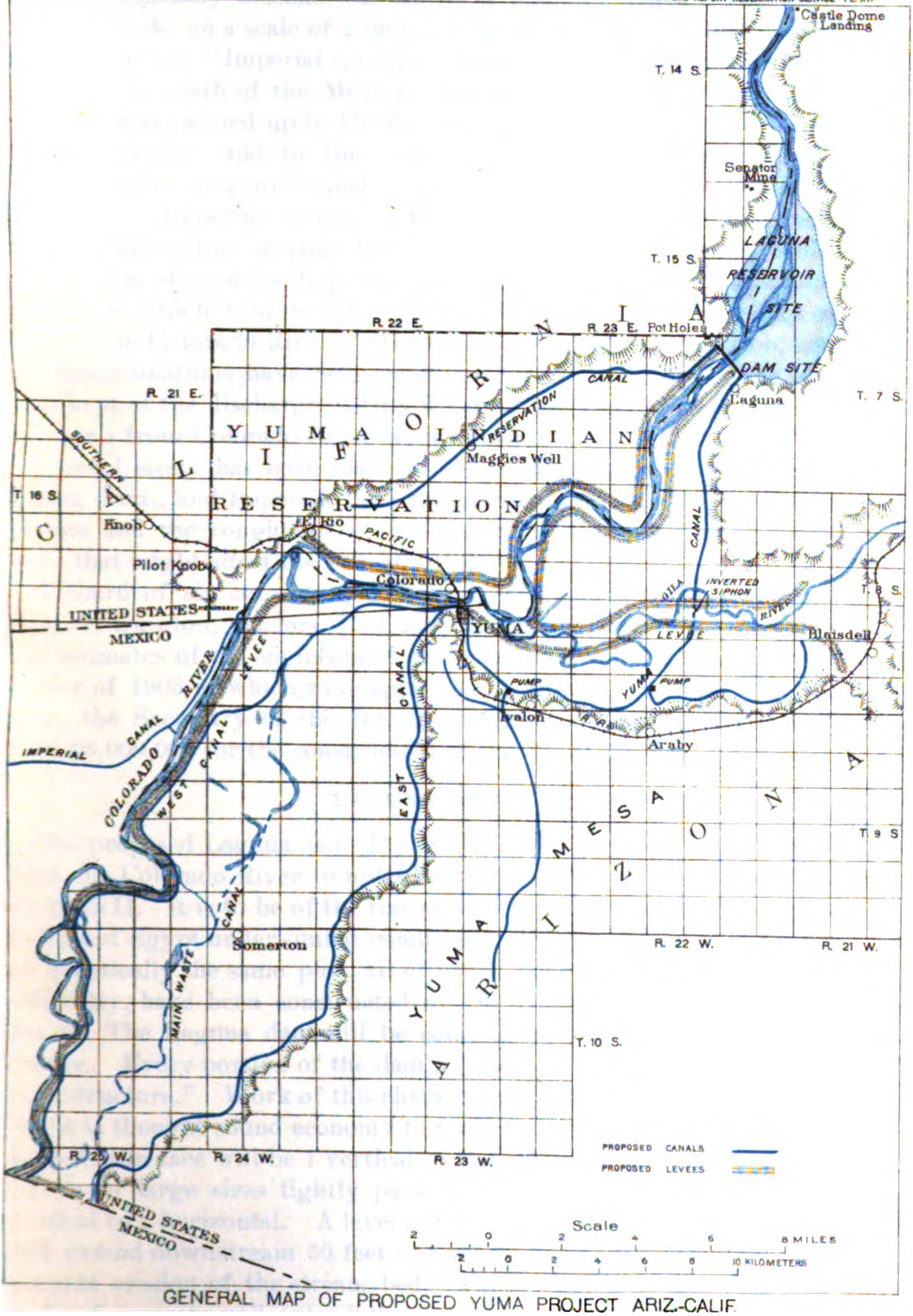
YUMA PROJECT.

The Yuma project contemplates the irrigation of land on both sides of Colorado River, in Arizona and California, in the vicinity of the town of Yuma, Ariz., as shown on Pl. XII. The soundings made for bed rock along Colorado River indicate that a high diversion dam is impossible, and that only the valley lands can be irrigated by gravity canals. The extent of the irrigable areas can not be stated absolutely until the canals and levees are finally located. It is now estimated that 97,000 acres will be irrigated in the valley, from which about 10 per cent must be deducted for sloughs and sand-dune land. Yuma Mesa has an area of about 92,000 acres, which can not be irrigated by gravity canals because of their elevation. The plan contemplates pumping water for 25,000 acres of this mesa immediately south of the town of Yuma.

PAST OPERATIONS.

During the winter season of 1902–3 topographic maps of this area, on a scale of 2 inches to the mile, with a 10-foot contour interval, were made to an elevation of 150 feet above river level. During the winter season of 1903–4 extensive preliminary surveys were made in connection with this project. These included the platting of topographic maps, on the scale of 100 feet to the inch, with a small contour interval, of the Laguna dam site and other localities explored farther upstream, and the making of borings for bed rock at all of these points. A similar map and borings were made at the site of the proposed Gila crossing. The route of the main canal in Arizona was surveyed and similar topographic maps were made. This survey covered 39 miles of canal location.

In addition, similar maps were made of the proposed canal in California, extending over a distance of 29 miles. South of Yuma transit-line surveys were made for the main canal, and a preliminary survey was made for a canal on Yuma Mesa, a total distance of 37 miles. Preliminary locations were made for levees on both sides of Colorado River and Gila River from Laguna dam to the Mexican boundary, a total distance of 78 miles. A drainage system including pumping



GENERAL MAP OF PROPOSED YUMA PROJECT ARIZ.-CALIF.

plants was projected on the topographic maps, and surveys were made for a preliminary estimate on the mesa pumping plant. The topographic work, on a scale of 2 inches to the mile, was extended to what is known as the "Imperial country," lying west of Colorado River and immediately north of the Mexican boundary line. This topographic mapping was carried up to 150 feet above sea level on the east side of Imperial Valley and to the distributing system of the California Development Company's canal on the west. This system is frequently called the "Imperial system." Extensive investigations have been made to determine seepage losses in canals, areas of irrigated lands, crop losses, etc., in the Imperial country in compliance with the joint resolution which Congress has passed concerning the diversions of water from Colorado River. Stream measurements, evaporation, and silt determinations have been continued on Colorado River, and records kept of the discharge of Gila River as well as all diversions made by canals from Colorado River below Yuma.

Careful study has been made of the canals now in operation near Yuma, Ariz., and Imperial, Cal., to determine the shape they naturally assume and the roughness of the bottom and sides, and of all conditions that might affect the velocity of flow.

A board of six consulting engineers, consisting of Messrs. Davis, Wisner, Quinton, Sanders, Hall, and Lippincott, examined the plans and estimates of the engineers of the Yuma project made during the winter of 1903–4, which were approved in April, 1904. On May 10, 1904, the Secretary of the Interior set aside from the reclamation fund $3,000,000 for the construction of the Yuma project.

LAGUNA DAM.

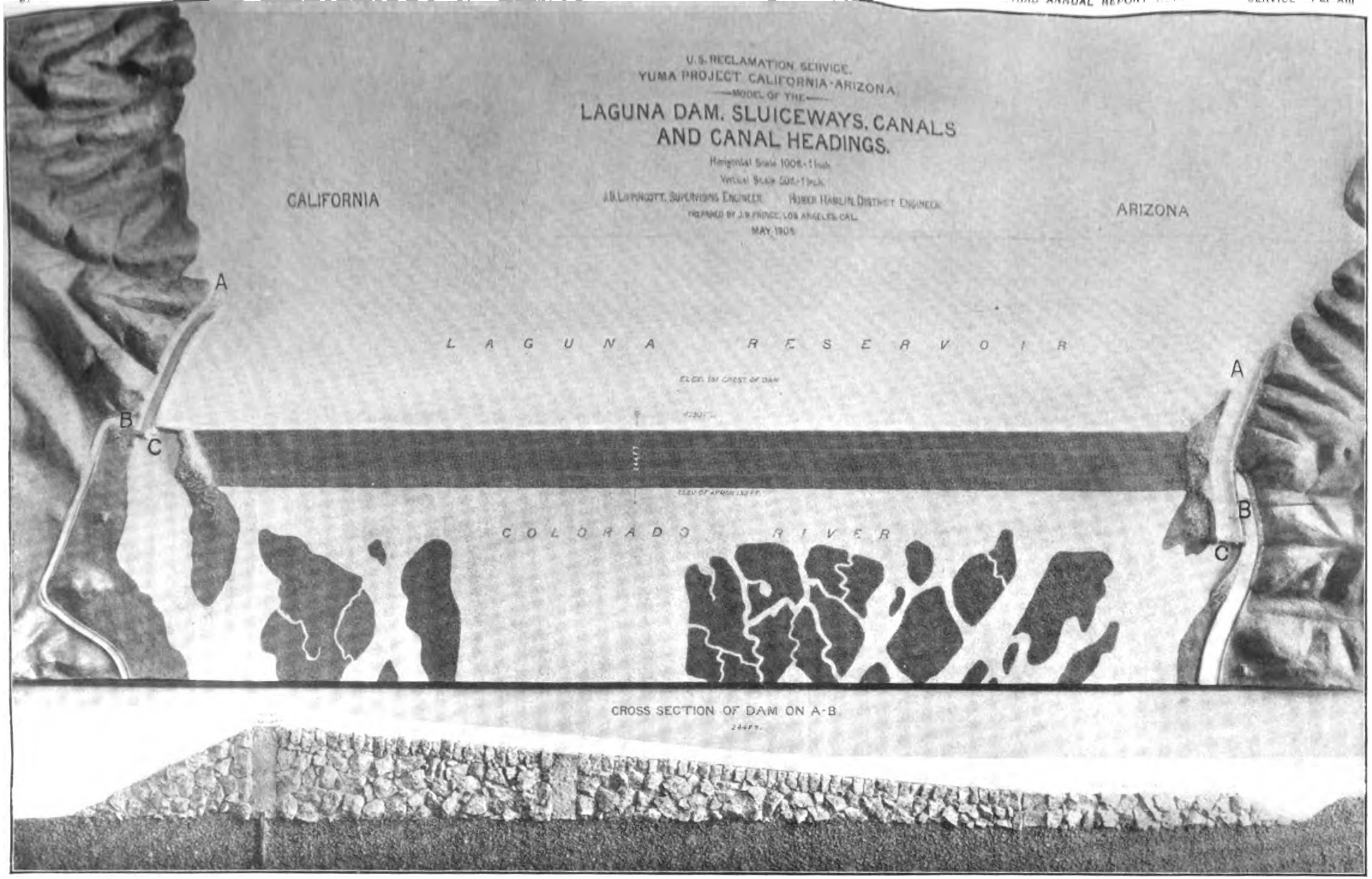
The proposed Laguna dam (Pls. XIII, XIV, XV) will divert water from the Colorado River 10 miles northeast of Yuma, Ariz., as shown on Pl. XII. It is to be of the Indian weir type, so successfully used in India and Egypt under similar conditions. (See Pl. XV.) Three dams on practically the same plan, all of which have served their purpose efficiently, have been constructed on the Nile within the last fifteen years. The Laguna dam will be constructed of stone, concrete, and timber. Every portion of the dam will be what is known as "permanent structure." Work of this character will, of course, be expensive, but it is thought sound economy to build this way. The slope of the downstream face will be 1 vertical to 12 horizontal, paved with rough rubble of large sizes tightly packed; that of the upstream slope, 1 vertical to 2 horizontal. A level apron composed of very large stones will extend downstream 50 feet beyond the toe of the lower slope, to prevent erosion of the stream bed. Three parallel longitudinal core walls of concrete will extend the entire length of the dam, to cut off percolating water and to hold the rock in place. A row of triple lapsheet piling will be driven below the upper core wall, to cut off percolation from the reservoir. The dam will be 4,780 feet long, with a maximum width of 257 feet and a maximum height of 19 feet above the bottom of the stream. It will raise the low-water level of the river about 10 feet.

SLUICEWAYS.

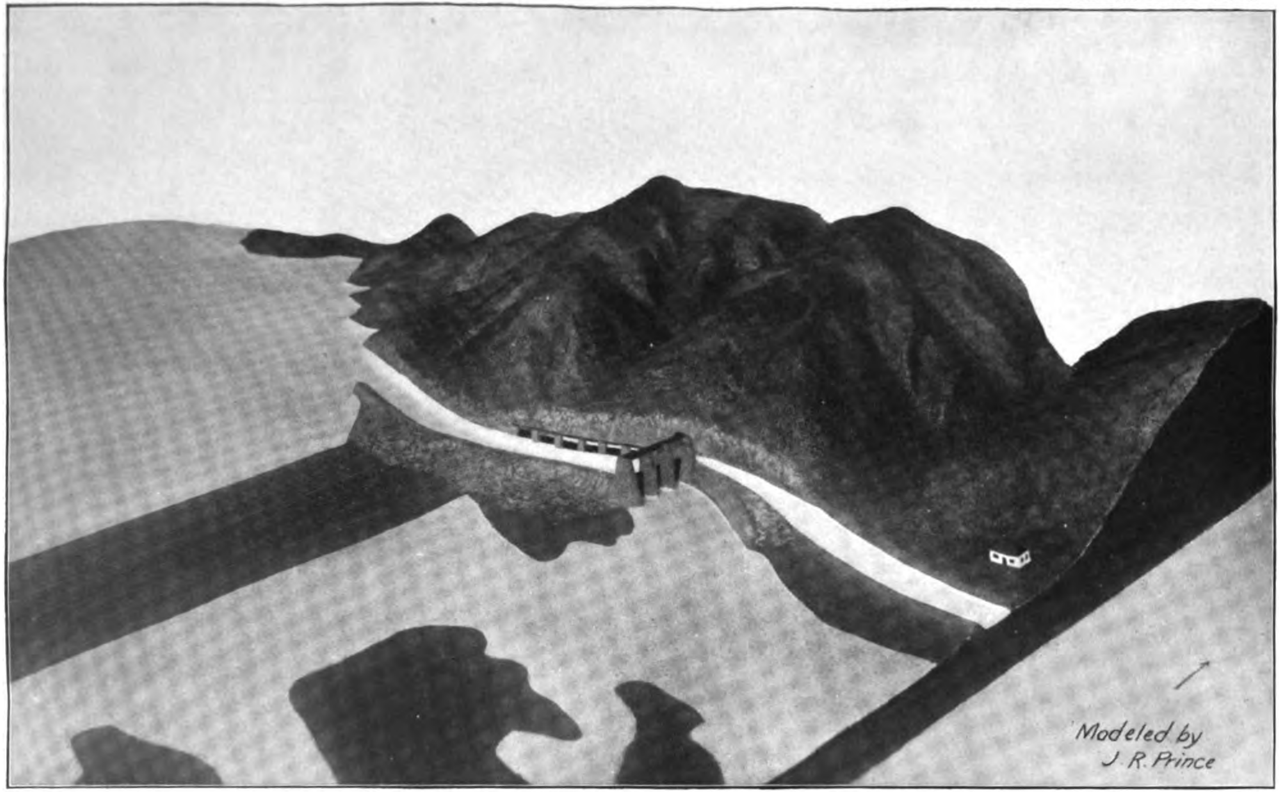
The disposition of the silt of the Colorado is one of the most difficult features of this undertaking. It is known that its amount is very large. As a result of a number of experiments it has been found that most of the silt is carried along near the bottom of the river and that the surface water is relatively free from sediment. It is estimated that the amount of silt which would be daily delivered into the Yuma canal, if diversion were made directly from the stream, would approximate 17,000 cubic yards of wet mud by volume. It is not believed to be possible for a canal to continuously operate successfully for irrigation of lands along the Colorado unless some very substantial arrangements are made at the head works for handling this silt. This and the fact that water must be held to nearly a fixed level at the canal heading for all stages of the river is believed to justify the expenditure proposed for these head works, which will cost approximately $1,000,000.

At the east end of the dam, constructed in solid granite and excavated to the depth of low water in the river, will be a sluiceway 116 feet wide, 18 feet deep, and 800 feet long. At the west end of the dam, also in granite, will be a sluiceway 40 feet wide, 18 feet deep, and 800 feet long, so planned as to permit of enlargement to meet possible future needs. These sluiceways will be closed at the outlet by large Stoney gates operated by electrical machinery.

The area of these sluiceways being so great relative to that of the canals, the movement of water through them will be slow, and most of the sediment will be deposited before reaching the canal intake. When sediment has accumulated on the bottom of the sluiceways to a considerable extent, the sluice gates will be opened and a very large volume of water will be allowed to escape, washing the silt out of the sluiceways and into the river below. It is estimated that the sluiceway on the Arizona side will discharge 24,000 second-feet and that on the California side 7,000 second-feet at high water. The ordinary low-stage flow of the Colorado is from 3,500 to 4,000 second-feet, so that the maximum capacity of the sluiceways will be about eight times the low-water flow of the river. At low water the quantity of silt carried by the river will be comparatively small, a relatively small quantity of water being required for sluicing. These figures are given for purposes of comparison only.


U.S. RECLAMATION SERVICE.
YUMA PROJECT CALIFORNIA-ARIZONA.
—MODEL OF THE—
LAGUNA DAM. SLUICEWAYS. CANALS AND CANAL HEADINGS.
Horizontal Scale 100ft.=1 Inch
Vertical Scale 50ft.=1 Inch
J.B. LIPPINCOTT, SUPERVISING ENGINEER.
HOMER HAMLIN, DISTRICT ENGINEER.
PREPARED BY J.B. PRINCE, LOS ANGELES, CAL.
MAY 1905
CALIFORNIA
ARIZONA
A
B
C
A
B
C
LAGUNA RESERVOIR
ELEV. 151 CREST OF DAM
244 FT.
ELEV. OF APRON 132 FT.
COLORADO RIVER
CROSS SECTION OF DAM ON A-B
244 FT.

PHOTOGRAPH OF MODEL OF LAGUNA DAM, YUMA PROJECT, ARIZONA-CALIFORNIA.



PHOTOGRAPH OF MODEL OF LAGUNA DAM, YUMA PROJECT, ARIZONA-CALIFORNIA.

It is planned to take the water into the canal intake by a skimming process over a long row of gates, so that the canal can be filled by drawing but 1 to 1.65 feet from the surface of the sluiceway, leaving the sediment in the bottom. If the capacity of the sluiceways is not sufficient for the exclusion of enough of the silt, they can at small expense be extended upstream, so as to increase the length of time required for the water to pass through them, thus permitting the settlement of a greater proportion of the silt.

In the Laguna reservoir the present grade of the river is about 1 foot per mile. A dam 10 feet high will make a settling basin 10 miles long, with a maximum width of 2¾ miles and an average width of 1 mile. Without doubt this reservoir will eventually fill with silt, but when filled it will, with its flat grade, broad channels, and low velocities, cause the deposition of much of the heavier silt. At flood time this sediment will be eroded and swept over the dam.

SLUICE GATES.

The outlet of the sluiceways will be closed by large Stoney gates, each gate closing an opening 33 feet 4 inches wide by 18 feet high. These gates will all be of the same pattern, consisting of a series of horizontal plate guides, spaced vertically, supporting the water-tight skin plates on the upstream side. Each gate will be counterbalanced and will move on trains of rollers. The hoisting mechanism will consist of a series of large gear wheels operated by electric motors—one for each gate—which will open or close one or all of the gates in a set as required. This mechanism will open and close the gates very quickly, and sluicing can be done whenever the silt accumulates in the sluiceway above. Three gates will be required on the Arizona side and one on the California side.

CANAL HEAD-GATES.

Designs for these gates are not yet completed. The gates will probably be similar to the sluice gates—of the same width and of the same length, but less height. Water will be admitted into the canals over these gates in order to skim off the relatively clear water from the surface of the sluiceways. They will be operated by hand, and will, when necessary, shut off all the flow into the canal headings.

PLANS AND SPECIFICATIONS.

Plans and specifications for the Laguna dam and sluiceway were prepared during the spring and summer of 1904. On July 28, 1904, the plans, estimates, and specifications for the Laguna dam and sluiceways were approved by a board of consulting engineers, consisting of Messrs. Davis, Wisner, Quinton, Sanders, Lippincott, and Hamlin.

YUMA CANAL.

This canal extends from the Laguna dam to Yuma, Ariz., a distance of 16 miles. (See Pl. XII.) At the dam it has a bed width of 61.7 feet and a depth of 8 feet, with a capacity of 1,600 second-feet. Several laterals lead from this canal, to irrigate the valley and mesa lands, reducing the size of the main canal, which at Yuma has a bed width of 42 feet, the depth still remaining 8 feet, with a capacity of 1,200 second-feet.

GILA CROSSING.

One of the most difficult problems in connection with this project is the crossing of Gila River. It has been considered necessary, in order to make this perfectly safe, to design a structure that will cross beneath the river, its top being several feet below the bed of the stream. It consists of four steel-concrete pipes of large diameter extending across the leveed section of the river, as shown on plan. (See Pl. XVI.)

YUMA VALLEY CANALS.

At Yuma the Yuma canal will divide into two branches, to be known as the East Side and West Side canals, as shown on Pl. XII. At this point will be located a wasteway and regulating gates, the waste water to be discharged back into the river.

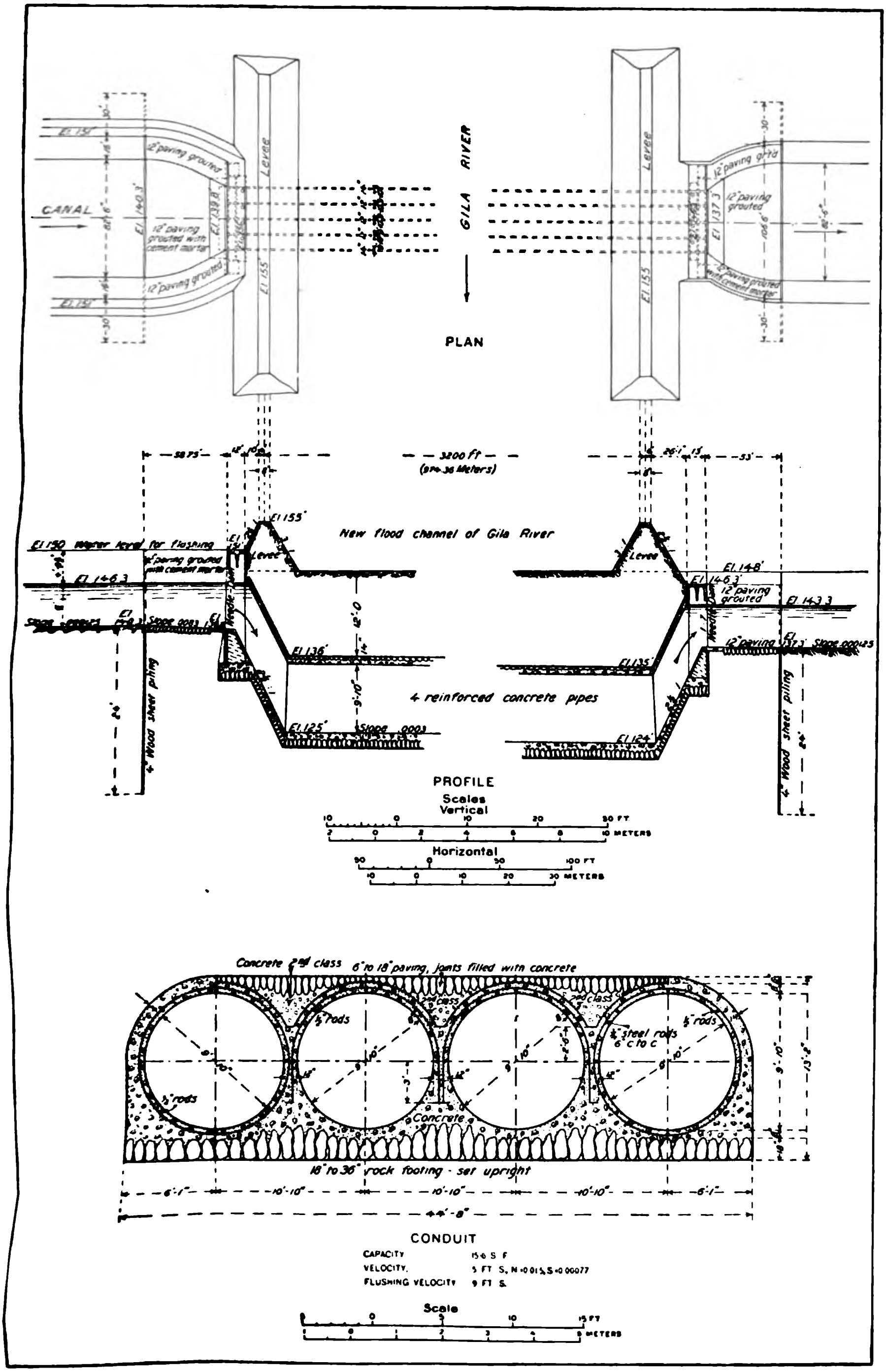
The East Side canal starts with a bed width of 13½ feet, a depth of 5 feet, and a capacity of 240 second-feet. It is located along the western foot of Yuma Mesa and will irrigate the lands on the east side of Yuma Valley. It gradually diminishes in size, until near the Mexican line it is merely a lateral. It will have a length of 15 miles to the last lateral.

The West Side canal starts from the same point, will have a bed width of 32 feet, a depth of 6 feet, and a discharge of 632 second-feet. It will run westerly from Yuma about 5 miles along the highest land in Yuma Valley, then southerly, following the high land near Colorado River, and will irrigate the land in the north end and on the west side of Yuma Valley. It also will gradually diminish in size, until it ends in a lateral near the Mexican line. It will have a length of 21 miles to the last lateral.

RESERVATION CANAL.

This canal starts at the west end of the Laguna dam on the California side. It will have a bed width of 14.7 feet, a depth of 4 feet, and a discharge of 200 second-feet. (See Pl. XII.) It will be located along the foot of the mesa on the Yuma Indian Reservation. Its length is 10 miles, with 3 main laterals aggregating 12 miles in length.

The total length of the main canals and laterals as now planned is 132 miles. In addition to this there will be the sublaterals and farmers' ditches which have not been located.



DETAILS OF PROPOSED GILA CROSSING, YUMA PROJECT, ARIZONA-CALIFORNIA.

YUMA MESA PUMPING PLANT.

It is planned to locate this pumping plant about 2 miles southeast of Yuma, Ariz., as shown on Pl. XII. It is intended to raise 300 second-feet about 70 feet and irrigate 25,000 acres of mesa land south of Yuma. The plant will be one of the largest in the United States. It is proposed to use crude oil for fuel. The main canal from the pumping plant will run directly south, and a branch will run northwesterly to irrigate the higher portion of the town. It is planned to line the canals on the mesa with concrete, in order to prevent excessive percolation. The main canal will be 7 feet on the bed, 7 feet deep, and will discharge 300 second-feet. It will be about 8 miles long.

Pumping will be necessary to reach about 7,000 acres in the upper Gila Valley. The power for doing this will be furnished by electricity generated at the Mesa pumping plant. The lift will vary from 5 to 25 feet.

The canals have been designed so that the water in them will flow at a higher velocity than in the sluiceways and settling basins above their heading. Such a velocity will carry along all the silt retained, and will cause a minimum loss by seepage and evaporation. The canal system will deliver 5.5 acre-feet of water to the irrigated lands.

They are designed to deliver the maximum amount needed (0.90 acre-foot per month) during the months of July, August, and September, the months of heaviest irrigation.

The lateral head-gates, drops, and the bridges at Yuma will be of concrete-steel or steel structures.

LEVEES.

Because of the annual summer rise of Colorado River and the occasional severe floods in Gila River a large portion of the lands along these streams is subject to overflow, which practically prevents residence on them or their farming without protective works. The levees, therefore, are considered an essential feature of the enterprise. The section of the levees adopted is one that has been developed by years of experience along Mississippi River. It will have a slope of 1 vertical to 3 horizontal on the water side and 1 vertical to 2½ horizontal on the land side; it will be 8 feet wide on top and will be built 5 feet above the high-water marks of the year 1903. These levees will be 4,000 feet apart (one on each side) along the Colorado and 3,200 feet apart on the Gila. About 59 miles of levees will be required in Arizona and 14½ miles in California, as shown on Pl. XII. The average height of these levees will be about 7½ feet.

DRAINAGE SYSTEM.

Because the valley lands are so flat and the level of the ground water is so near the surface it is considered necessary for their permanent irrigation to construct a drainage system. A main drainage canal has been designed to run through the central portions of the areas to be irrigated, and when possible the natural drainage lines of the country will be utilized and deepened to such a depth that they will carry the water returning from irrigation or seepage through the levees during high-water stages of the river.

When lands in any district tend to become alkaline they may be connected by means of local drainage canals with these main drains, and in this manner be kept free from alkali by holding down the ground-water level. During the greater portion of the year, when the river is low, this drainage water will be discharged into the stream, but when the river is in flood its surface will be too high to permit the discharge of the drain by gravity. Pumping plants will therefore be designed to lift the drainage water over the levees during the flood period and thus prevent the lands becoming water-logged.

CROPS.

The reports of the Department of Agriculture, as well as experience in farming, indicate that the valley lands in the Yuma project are exceedingly fertile and are suitable for the production of staple, particularly forage, crops and grain. It is believed that the plant food carried by the silt and in solution by the river water will perpetually fertilize the irrigated lands. The mesa lands are adapted to the growth of early vegetables and fruit, which will probably come into the market earlier than that from any other section of the United States. From the experiments made it seems probable that citrus and many varieties of semitropical fruits may be raised on the mesa with profit.

WATER USERS' ASSOCIATION.

In November, 1903, the Yuma County Water Users' Association was organized for the purpose of securing contracts with landowners for water rights, for adjusting the claims of the various canal companies, and for the general administration and operation of the canal system when completed. At present about 98 per cent of the land which has passed into private holdings is under contract to take water according to the provisions of the reclamation act.

COST.

Revised estimates have been made for the canal system, and particularly for the Gila crossing. Mr. Homer Hamlin has been investigating the large Stoney gates in use on the Chicago drainage canal, at Sault Ste.

Marie, and the bear trap gates on Ohio and Allegheny rivers; also the levee work on Mississippi River, with a view of obtaining information necessary for the Yuma project. Mr. O. H. Ensign, mechanical and electrical engineer, has been investigating the feasibility of pumping water from the Yuma canal onto the mesa by means of steam pumping machinery. While final results have not been reached in this connection, they are considered as sufficiently satisfactory to justify estimating on a canal of increased capacity to provide for a water supply for these mesa lands.

The entire cost of this enterprise, provided all the valley lands are irrigated as indicated above, will amount to about $40 per acre irrigated. It is entirely possible, however, that as construction work proceeds this cost may be somewhat increased or lessened, although an effort has been made to cover all contingencies, and estimates of cost have been liberal.

PRESENT OPERATIONS.

The present operations consist of the preparation of plans and estimates, together with specifications, acquisition of rights of way, etc., on this project. Homer Hamlin, district engineer, is in direct charge of the work at Yuma, and J. B. Lippincott is supervising engineer for the project.

OWENS VALLEY PROJECT.

Two brief statements are appended concerning the details relating to Owens Valley, California; the first of these is from a report by J. C. Clausen, concerning water supply, and the second is from notes by Willis T. Lee on examination of Owens Valley.

WATER SUPPLY IN OWENS VALLEY.[a]

It has been found difficult to ascertain the exact amount of surplus water available for storage in the Owens Valley. Although a good record of all streams and canals has been obtained, the canals and natural streams tributary to Owens River are so interwoven that it is difficult to tell what canals draw directly from the possible storage and what canals are fed by the tributary streams and return waters.

LONG VALLEY RESERVOIR SITE.

The following table gives the results of measurements of Owens River, Rock Creek, and Pine Creek during 1903 and 1904; it also shows the amount of water necessary to supply existing canals and the amount that will then remain for storage in Long Valley reservoir.

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[a] From report by J. C. Clausen.

Water available for storage in Long Valley reservoir.

Month.	Source of supply.			Canals to be supplied.				Available for storage at Long Valley reservoir site.
	Owens River.	Rock Creek.	Pine Creek.	Owens River canal.	Bishop Creek canal.	Farmers' canal.	McNally canal.	
1903.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
August[a]	10,379	1,189	472	1,893	4,720	677	3,714	1,036
September	9,937	1,071	280	2,338	5,321	809	2,713	107
October	10,576	922	664	1,452	2,239	1,047	....	7,424
November	9,699	1,071	702	....	....	952	....	10,520
December	9,900	1,230	775	....	....	922	....	10,983
Total for period	50,491	5,483	2,893	5,683	12,280	4,407	6,427	30,070
1904.								
January	9,629	1,070	799	....	....	941	....	10,557
February	12,706	1,179	713	196	1,524	874	....	12,004
March	15,968	1,451	793	2,029	480	615	....	15,088
April	11,990	1,250	536	2,464	4,945	607	3,007	2,753
May	18,416	3,074	1,334	2,767	6,359	1,156	4,919	7,623
June	31,656	5,456	8,450	1,993	2,505	1,250	4,760	35,054
July	26,317	3,720	4,304	2,029	6,087	984	6,148	19,093
August	20,660	3,628	2,705	2,152	5,226	1,599	(b)	18,016
September	16,721	1,726	714	1,706	7,319	1,131	(b)	9,005
October	16,356	2,890	1,722	....	....	553	....	20,415
November	14,638	2,142	1,488	....	....	357	....	17,911
December	13,404	1,703	1,076	....	....	350	....	15,833
Total for year	208,461	29,289	24,634	15,336	34,445	10,417	18,834	183,352

[a] Estimated from partial record for month.

[b] No record.

From a general knowledge of conditions it is believed that the four canals named in the table are the ones that must be satisfied before storage is possible. This is confirmed by the results for September, which show that at that time the river below the lowest canal was dry. The table shows that the amount of water passing through Long Valley reservoir site in 1904, and available for application on new land, was 183,352 acre-feet.

The total consumption of the four canals mentioned in the table is 79,032 acre-feet. This is probably much more than they beneficially use, and with good management perhaps 25,000 acre-feet of this amount could be stored.

RECONNAISSANCE IN OWENS VALLEY.[a]

An examination of Owens Valley was made during the summer of 1904 for the purpose of ascertaining the quantity, quality, and general condition of the ground waters. The investigation included the following subjects: (1) The origin and recent history of the valley; (2) the water supply entering the valley; (3) the recent history of Owens

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[a] From report by Willis T. Lee.

Lake and its relation to the waters of the valley; (4) the geologic formations, especially those of recent origin.

Owens Valley lies in east-central California, at the eastern base of the Sierra Nevada. It is about 100 miles long, with a strip of agricultural land about 5 miles wide in the center. The highest portion of the Sierras rises abruptly on the west and the White Mountains on the east. The valley is consequently located in such a position that streams enter it from regions of great precipitation, bringing a large supply of water.

At the mouth of each stream entering the valley from the mountains is a detrital cone. A large part of the water of the stream enters the loose material of this cone and finds its way to the lower part of the valley as underground water. The streams are numerous on the western or Sierra side of the valley and contribute large amounts of water to the underground supply.

Owens Lake is one of the residual saline lakes of the Basin region, and is fed mainly by Owens River. The lake has been diminishing in volume for about ten years. A quantitative computation of inflow and evaporation indicates that this diminution is caused by increased evaporation, due to the irrigation of lands in the valley rather than to any decrease in precipitation.

The material in the floor of the valley is made up of lake deposits and coarse detritus derived from the neighboring mountains. The alternation of coarse and fine material gives rise to artesian or subartesian conditions. At Keeler a strong artesian flow is encountered. At Bishop artesian water is found under very slight pressure. At many other points the water rises in wells, but not enough to flow at the surface.

The surface waters are abundant and lie at no great depth. A superabundance of power is offered by the mountain streams. It is thought that the pumping of water for irrigation might be carried on more profitably in Owens Valley than in many places where that method is now employed to secure irrigation waters.

In addition to an investigation of the water supply, observations were made on (1) building stone for construction purposes, (2) materials for the manufacture of cement, and (3) the geologic conditions at Long Valley dam site.

There is no lack of building material of the best quality. The granite of the Sierra is close grained, firm, and undecomposed even at the surface.

The materials requisite for the manufacture of cement are abundant and are found at no great distance from the site of the proposed dam. Volcanic ash, which may be used in making puzzolan cement, is abundant at the dam site. There is also a material at Owens Lake which seems to be a natural cement and which by the addition of clay and lime may make a good hydraulic cement.

The abutments of the proposed dam were examined and a trip was made through the reservoir site. The proposed reservoir is thought to be an old lake bed. The lake was probably formed by an outburst of lava which threw a broad barrier across Long Valley, damming the waters entering the valley. In cutting through the lava field the overflow of this lake carved the narrow canyon across which it is proposed to build a dam and restore the lake for a reservoir.

The volcanic material is a more or less consolidated ash. At the dam site the rock, although it is soft, is tough, resistant, and fine grained. Judging from a field examination, there is reason to believe that the material is strong enough to withstand any strain required of it in the construction of a dam, and its texture is sufficiently fine to prevent any serious leakage.

KLAMATH PROJECT.

GENERAL STATEMENT.

The Klamath basin is situated in Klamath County, Oreg., and in Modoc and Siskiyou counties, Cal. It includes the valleys of Lost River and that of the upper portion of Klamath River (Pl. XVII).

The nearest railroad station is Pokegama, Oreg., which is 36 miles from Klamath Falls. From Pokegama connections are made with the main line of the Southern Pacific Railway at Thrall, Cal., a distance of 30 miles, by means of the Klamath Lake Railway. It is expected that a railway line will be constructed into the basin in the near future.

The watershed area above the Klamath basin extends from the Sierra Nevada on the west to the Warner Mountains on the east and to Crater Lake on the north. The Klamath Indian Reservation is included within this area. The principal streams of the watershed are Williamson and Sprague rivers, which drain into Upper Klamath Lake, and Lost River, which empties into Tule Lake. Williamson River is fed by some very large springs, the water supply apparently coming in great part from the country around Crater Lake. Sprague River drains the country northeast of Klamath Lake.

Upper Klamath Lake has an area of about 57,000 acres. If the marginal swamp lands are included, this area is over 100,000 acres. The flow of the rivers is regulated by this large area of lake and swamp. From the lake Link River falls about 56 feet in 1 mile to the town of Klamath Falls, the head of Klamath River. From Klamath Falls to Keno the grade is practically level. At Keno the lower rapids of the river begin.

Lost River receives its water supply largely from Willow and Miller creeks. Willow Creek during flood season empties a part of its water into Clear Lake. When the creek falls the lake begins draining into Lost River, and in this way the flood discharges of Lost River are regulated. The area of Clear Lake is about 10,000 acres and that of the marginal swamp lands about 5,000 acres.

Lost River is an interstate stream, carrying water from California through Oregon and back into California.

Tule Lake is situated on the interstate boundary line. Its area is 94,000 acres. It has no outlet.

Lower Klamath Lake is also situated on the interstate boundary line between Oregon and California. This lake receives its supply from Klamath River. During flood seasons water is discharged from the river into the lake and during the low stages of the river from the lake into the river. The area of Lower Klamath Lake is approximately 30,000 acres and that of the adjacent swamp land approximately 50,000 acres.

INVESTIGATIONS OF PROJECT.

The basin of Klamath River was reported upon by John T. Whistler, engineer, and by H. E. Green, engineer, in October, 1903. These reports were preliminary and were considered sufficient justification for further investigations.

John T. Whistler, engineer, in the spring of 1904 established the following gaging stations in the basin of Klamath River:

Link River, at Klamath Falls.
Tule Lake, near Merrill.
Lost River, at Langells Valley.
Sprague River, at Yainax.
Sprague River, 5 miles below Yainax.
Lost River, at Olene.
Upper Klamath Lake, at Pelican Bay.
Klamath River, at Keno.

In May, 1904, Messrs. T. H. Humpherys, engineer, and F. S. Chapman began a general investigation of the Klamath basin. In the latter part of June, 1904, J. B. Lippincott, supervising engineer, made an extended trip through the basins of Klamath and Lost rivers with T. H. Humpherys. No extensive surveys had been made at that time, Mr. Humpherys having spent his time in acquainting himself with the general situation and arranging for more detailed work. The results of these preliminary studies, together with the personal reconnaissance of J. B. Lippincott, supervising engineer, aided by the topographic maps of the Geological Survey, led to the conclusion that Clear Lake, at the head of Lost River, and Horsefly, on Miller Creek, are feasible reservoir sites. The water impounded in the Clear Lake reservoir, which is in California, can best be used in Oregon. The Horsefly reservoir is situated in Oregon, and the waters can best be used in Oregon.

Upper Klamath Lake is a feasible reservoir for the storage and regulation of the water supply for Klamath Valley. A diversion conduit from this lake would serve lands in both Oregon and California.

By lowering the water in Klamath River by means of a cut at the head of the rapids at Keno, Lower Klamath Lake will be partially drained and the marginal swamp lands exposed. The lowering of the river will permit the waste and drainage water from Lost River to be turned into Klamath River, thus shutting off the supply from Tule Lake, which it is believed will rapidly shrink by evaporation and expose large areas of irrigable lands.

Klamath River, Lower Klamath Lake, and Tule Lake, being officially navigable, could be drained only by proper legislative authority granting this permission.

SURVEYS.

In July, 1904, surveys of the Klamath basin were begun under the direction of T. H. Humpherys, engineer. Angle-line surveys for preliminary canal lines and for determining the irrigable areas were made. These surveys include Langells, Alkali, Poe, Swan Lake, and Klamath valleys. Topographic surveys were made of Clear Lake and Horsefly reservoir and dam sites and of Klamath River at the head of the rapids at Keno. Surveys of Lower Klamath Lake, Tule Lake, and Klamath River between Klamath Falls and Keno were made, and soundings taken to determine the depth of water and character of bottom.

The canal-line surveys have been platted on a scale of 5,000 feet to an inch and the irrigable lands mapped in this way.

Preliminary plans for storage reservoirs, canals, and headworks and an estimate of the cost of construction have been made. These plans and estimates have been carefully reviewed by the board of consulting engineers, and the project has been favorably reported on by this board and has been approved by the Secretary of the Interior.

The following is a general summary of the preliminary plans and the results of a study of the conditions in Klamath Valley:

AREAS OF IRRIGABLE LANDS.

The following areas of irrigable lands have been found in the Klamath basin:

Upper project, irrigable from Clear Lake and Horsefly reservoirs.

	Gross.	Net.
	Acres.	*Acres.*
Langells Valley	29,927	26,935
Yonna Valley	16,354	14,719
Poe Valley	3,884	3,496
Upper Klamath Valley	3,562	3,206
Total	53,727	48,356

Lower project, irrigable from Upper Klamath Lake.

	Gross.	Net.
	Acres.	*Acres.*
Klamath Valley	68,405	61,564
Lower Klamath Lake and swamp	89,476	71,581
Poe Valley	8,503	7,652
Tule Lake bed	94,496	47,248
Total	260,880	188,045

Total net area irrigable land, 236,401 acres, divided as follows:

	Per cent.	Acres.
Public lands	45	106,929
Private lands	55	129,472
Total	....	236,401

Of this area, 90,000 acres are in California and 146,401 acres in Oregon.

WATER SUPPLY.

On October 25, 1903, Link River was measured at Klamath Falls by H. E. Green, at its low-water stage, and the volume discharged was 2,000 second-feet. It was stated then that the river was lower than it had been at any previous time for twelve years. The discharge of Link River at Klamath Falls from May to November, 1904, is as follows:

Estimated discharge of Link River at Klamath Falls.

Date.	Mean monthly discharge.	Total monthly discharge.
1904.	*Second-feet.*	*Acre-feet.*
May 15-31	8,601	....
June	6,439	383,147
July	3,862	237,465
August	2,279	140,130
September	1,730	102,942
October	1,751	107,665
November	1,872	111,392

The discharge of Lost River into Tule Lake at Merrill, Oreg., from August to November, 1904, is given in the following table:

Estimated discharge of Lost River at Merrill, Oreg.[a]

Date.	Mean monthly discharge.	Total monthly discharge.
1904.	*Second-feet.*	*Acre-feet.*
August	176	10,822
September	144	8,569
October	139	8,547
November	134	7,974

[a] These results are subject to slight changes when more data are obtained and rating curves revised.

The watershed area above the Clear Lake reservoir is estimated at 576 square miles; that above the Horsefly at 200 square miles. The watershed area above the Horsefly is fairly well timbered and apparently has a fair rainfall and winter stream flow. Its elevation is 4,792 feet. The drainage basin above Clear Lake is covered with a sparse growth of pine trees. The elevation of the lake is 4,533 feet, as shown by the contour maps. The rise of the lake during the winter of 1903–4 would indicate an inflow of about 150,000 acre-feet additional to the discharge of Lost River, which was continuous during the inflow period.

Lost River discharges into Tule Lake, the area of which is 94,000 acres. During the winter of 1903–4 this lake had a net rise of 7 feet, indicating an inflow of 658,000 acre-feet. The season of 1903–4 was one, however, of unusually large rainfall.

Permanent gaging stations are now maintained on Link River at Klamath Falls and Keno, on Lost River at the Clear Lake dam site and Merrill, on Miller Creek at the Horsefly dam site, and on Sprague River. Gage rods are maintained on Upper Klamath Lake and Tule Lake.

CLEAR LAKE RESERVOIR.

The areas and capacities of the Clear Lake reservoir are as follows:

Capacity of Clear Lake reservoir.

Contour.	Area.	Capacity.
	Acres.	*Acre-feet.*
94	....	....
102	14,620	[a] 79,613
105	18,689	129,576
110	21,340	229,648
115	23,275	341,186
120	25,193	462,356

[a] Water surface, 1904.

In order to utilize the entire storage capacity of the present lake, it is proposed to excavate a channel from the lake to the dam, a distance of about 6 miles. This channel is to be 60 feet wide on the bottom and requires the excavation of approximately 500,000 cubic yards in its construction.

The dam site for the Clear Lake reservoir is on Lost River about 2 miles below the mouth of Willow Creek. The type of dam planned is a loose-rock dam with a facing of earth on the upstream face. The dimensions of the dam are as follows:

Dimensions of dam for Clear Lake reservoir.

	Feet.
Top length	850
Top elevation	125
Bottom elevation	95
Top width of dam	20
Upstream slope	3 to 1
Downstream slope	1½ to 1

Material required, 27,047 cubic yards of rock and 15,969 cubic yards of earth. Outlet, two 5 by 6 foot concrete conduits, closed by cast-iron sluice gates. Capacity of outlet at low water, 500 second-feet. Channels for a distance of 50 feet above and below the dam to be paved 1½ feet thick with loose-rock paving.

HORSEFLY RESERVOIR.

The areas and capacities of the Horsefly reservoir are as follows:

Capacity of Horsefly reservoir.

Contour.	Area.	Capacity.
	Acres.	*Acre-feet.*
120	8	....
125	33	103
130	64	345
135	188	975
140	1,070	4,120
145	1,735	11,133
150	2,143	20,828
155	2,577	32,628
160	2,908	46,340
165	3,188	61,580
170	3,458	78,195
175	3,707	96,108
180	3,978	115,320
185	4,253	135,898
190	4,534	157,865

Type of dam planned, loose rock with an upstream facing of earth, of the following dimensions:

Dimensions of dam for Horsefly reservoir.

	Feet.
Top length of dam	480
Elevation of top of dam	190
Elevation of bottom of spillway	182
Elevation of bottom of outlet tunnel	125
Elevation of bottom of dam	112
Top width of dam	20
Upper slopes	3 to 1
Lower slopes	1½ to 1

Outlet tunnel, 7 feet diameter, 463 feet long, excavated in rock.

Capacity of outlet at low water, 500 second-feet.

CANAL SYSTEMS.

Water from the Clear Lake reservoir for the Upper project is carried by the Lost River channel a distance of about 5 miles, and then by a main canal along the west side of Lost River to the distributing canals of Langells, Yonna, Upper Poe, and Upper Klamath valleys.

The canal system of the Upper project contemplates two crossings over Lost River and one over Miller Creek. These crossings are to be made by means of inverted siphons of reenforced concrete. The upper crossing on Lost River at the head of Langells Valley will be 460 feet long, 6.5 feet in diameter, and will have a maximum head of 60 feet. It will be used for carrying water to East Langells Valley.

The Lost River lower crossing at Harpolds dam will be 710 feet long, 6.5 feet in diameter, and will have a maximum head of 90 feet. This crossing is on the Langells Valley west line and will carry water for Yonna and Upper Klamath valleys.

The Miller Creek crossing is on the Langells Valley east line. It will be 2,043 feet long, 3.5 feet in diameter, and will have a maximum head of 60 feet.

The entire canal system from the Clear Lake reservoir includes approximately 70 miles of main canals and 75 miles of laterals. The Horsefly reservoir will be used as an auxiliary water supply for the Upper project. Capacity of main canal for Upper project, 452 second-feet.

Water for the Lower project is to be diverted from Upper Klamath Lake at the head of Link River, a main canal being carried down on either side of the valley. From the east side main canal a high line will be carried into Poe Valley and along the edge of the mountains to the lands north of Tule Lake. This will cross Lost River at Olene, and from it a branch will recross at Griffith crossing to reach the high land between Lost River and Lower Klamath Lake. These crossings are to be of reenforced concrete. The Olene crossing will be 690 feet long, 8.5 feet in diameter, and will have a maximum head of 60 feet. The Griffith crossing will be 11,340 feet long, 6.5 feet in diameter, and will have a maximum head of 70 feet.

The south branch of the main canal will carry water for the lands of Klamath Valley west of Lost River, the bed of Tule Lake, and the eastern part of Lower Klamath Lake. One lateral from the south branch will cross Lost River at the site of the present Adams canal crossing. Length of crossing, 520 feet; diameter of pipe, 7 feet; maximum head, 50 feet. The capacity of the main canal in east Klamath Valley will be 1,378 second-feet.

The main canal on the west side of Klamath Valley will carry water to the lands west of Klamath River, between Klamath Falls and Keno, and to the western portion of Lower Klamath Lake. This line crosses Klamath River at Keno. Length of crossing, 1,765 feet; diameter of pipe, 8 feet; maximum head, 60 feet. Capacity of main canal west side, 281 second-feet. The entire canal system of the Lower project includes 103 miles of main canals and 180 miles of laterals.

The diversion works at the head of Link River will be of concrete, fitted with cast-iron gates.

KENO CUT.

The lowering of Klamath River at Keno and the drainage of Lower Klamath Lake will be effected by making an open cut through the point of a ridge at the head of the rapids below Keno. This diversion is sufficient to lower the water surface of Klamath River 12 feet below the present water level, with a maximum discharge of 10,000 second-feet. Length of cut required, 5,500 feet; volume of excavation, earth 200,000 cubic yards, rock 715,333 cubic yards.

DRAINAGE.

In addition to the lowering of Klamath River, a drainage canal for the flood and waste waters of Lost River will be constructed from Olene to Klamath River, a distance of 10 miles. Water will be diverted from the present channel of Lost River at Olene by means of a concrete diversion weir 6 feet high and 273 feet long at top. This drainage canal is 60 feet wide on the bottom and has a capacity of 600 second-feet. It is carried under the south branch main canal by a series of five concrete arch conduits.

The channel of Klamath River between Klamath Falls and Keno and that from the Lower Lake to the river will be opened to permit of these streams being used for navigation. This necessitates the removal of a rock reef from Klamath River about 2 miles below Keno.

In the Upper project drainage channels are provided for the Langells Valley swamp and Yonna Valley lake. Throughout the entire project a system of lateral drainage is provided where the topography and soil demand it.

POWER POSSIBILITIES.

The falls of Link River above Klamath Falls and of Klamath River below Keno present possibilities of power development. No plans for the utilization of this power have been made. It is believed, however, that the power may be advantageously used for pumping water to lands not reached by the gravity canals.

PUBLIC LAND WITHDRAWALS.

When investigations were begun on the Klamath project, it was deemed advisable to withdraw from entry all public lands within the proposed project. These withdrawals include all public lands in the Clear Lake and Horsefly reservoir sites, the lands along Klamath River for power, and also such townships as contain public irrigable lands as shown by the land records.

EXISTING CANALS.

The Little Klamath Water Ditch Company's canal (the Adams ditch) carries water from Lower Klamath Lake near the State line for the irrigation of lands along the north shore of Tule Lake. This is the largest canal in the district. The Van Brimmer ditch takes water from the Adams ditch and distributes it to the lands to the north and west of Tule Lake. Another canal, known as the Ankeny ditch, carries water from Upper Klamath Lake to that portion of Klamath Valley between Klamath Falls and Lost River. This canal was constructed some years ago, has passed through bankruptcy, and is now irrigating 5,000 or 6,000 acres of land. There are one or two small canals in other portions of the valley.

About January, 1904, the Klamath Canal Company began the construction of a canal from Upper Klamath Lake toward Tule Lake. Work on this canal was carried on during the latter part of the year 1904, and a small tunnel has been driven through the hills between the upper lake and the valley.

Options on these private canals have been secured, and it is anticipated that all the lands thereunder will be signed under the reclamation act.

CLIMATE.

The climate of the Klamath Valley is mild. The summers are warm and dry, but not excessively hot. Snow falls during the winter, but extremely low temperatures are seldom experienced. The annual rainfall is light, averaging about 10 inches.

The following table shows the precipitation and evaporation at Keno from August, 1904, to March, 1905, inclusive, from observations made by the Reclamation Service:

Precipitation and evaporation at Keno, Oreg.

	Precipitation.	Evaporation.		Precipitation.	Evaporation.
1904.	*Inches.*	*Inches.*	1905.	*Inches.*	*Inches.*
August	0.00	6.92	January	2.08	1.64
September	1.58	5.09	February	1.91	.91
October	2.08	1.72	March 1 to 24	1.19	.76
November	1.50	1.59	Total	13.91	20.27
December	3.57	1.64			

The irrigation season in Klamath Valley is approximately from May 15 to September 15, a period of four months.

AGRICULTURAL POSSIBILITIES.

The lands under the Klamath project were examined in November, 1904, by Mr. Thomas H. Means, engineer of soils. The following is abstracted from Mr. Mean's report:

The soils of the Klamath project are formed largely from the disintegration of volcanic rock and associated débris of volcanic origin. Soils of this character are generally uniformly fertile.

Two principal series of soil are found—upland and swamp soils or lake bottom areas. The upland soils are of fine texture and classify largely as sandy and silt loams. They are specially adapted to grains and should become important also in the production of alfalfa and root or tuber crops.

The swamp and bottom lands are at present very wet and will require proper drainage before cultivating. These soils differ from the upland soils in that they carry large amounts of organic decomposition products interstratified with deposits of volcanic ash and sedimentary material. The tilth and fertility of the swamp soils when brought under cultivation should be unquestionably good. Soils of this character are specially adapted to certain crops of high value. The dairy interests could likely be highly developed on such lands and the production of crops such as celery, onions, cranberries, or asparagus could likely be made successful.

The value of the nonirrigable lands is small. At the present time the alfalfa lands are worth from $20 to $30 per acre in the Klamath basin. With proper development such lands may be doubled in value, as has been found in other parts of Oregon and Washington. The fertility of the soils is, as a rule, good. The production of alfalfa and stock has already been proved successfully. The production of sugar beets, cereals, and apples, such crops as hops and celery and root crops seem also assured. With these crops the future development of the country can be left to the individual inclinations of the farmers. There can be no question as to the profitableness of these lines of agriculture to the farmer.

PRESENT OPERATIONS.

The present operations consists of making topographic and other surveys for canal location, together with the preparation of plans and estimates. J. B. Lippincott is supervising engineer for the project, and T. H. Humpherys, project engineer, is in charge of the work.

OPERATIONS IN COLORADO.

By A. L. Fellows.

The earlier work of the Reclamation Service in Colorado has been described in the First Annual Report of the Reclamation Service, pages 129 to 160, and in the Second Annual Report, pages 162 to 250.

During the past year principal attention has been devoted to the Uncompahgre Valley project, although reconnaissance has been continued throughout various parts of the State, a number of reservoir sites have been surveyed and a number of irrigation projects studied.

The White River and Grand Valley projects have been held in abeyance, although they have not been abandoned.

The following pages give essential facts concerning the progress upon the Uncompahgre Valley project, and statements showing the status of other projects and lines of investigation in Colorado.

UNCOMPAHGRE VALLEY PROJECT.

Reports concerning the Uncompahgre Valley project may be found in the First Annual Report of the Reclamation Service, pages 132 to 149, and in the Second Annual Report, pages 182 to 200.

The work done on this project from November 1, 1903, to October 31, 1904, is described in the following pages. During this period the investigations and surveys have been directly under the charge of I. W. McConnell, engineer, and assistants.

The work of surveying has been directed in general to unfinished topography and to location work on the Gunnison tunnel, the south, west, and east canals, the tunnel road connecting the two ends of the proposed Gunnison tunnel, the telephone line connecting the Montrose office with the tunnel and the canals to be constructed first, and the reservoir sites and possible drainage system.

Other investigations have covered forestation, hydrography, classification of lands and study of soils, establishment of temporary and permanent headquarters, compilation of estimates and reports, and mapping and designing.

The Uncompahgre Valley Water Users' Association has also gone on with its work, and has cooperated with the officers of the Reclamation Service.

The work accomplished under each of these subdivisions will be described.

TOPOGRAPHIC WORK.

During November and December, 1903, and January and February, 1904, topographic work in the northern part of the valley was carried to completion, approximately 20 square miles of that region being covered. Since that time small outlying sections of the valley, which it has been found desirable to include within the limits of the project, have been surveyed, and at the present time the topographic map of the valley is practically completed, with the exception of such detail topography as it may be necessary to take from time to time in connection with the location of canals and other structures. The valley topography has been on a scale of 1,000 feet to the inch, with 10-foot contours.

This work has been found to be of the greatest possible advantage in properly locating headgates and canals for the best irrigation of the lands to be benefited.

LOCATION SURVEYS.

GUNNISON TUNNEL.

During the winter of 1903-4 investigations were carried on with a view to determining whether a new line from Gunnison River to Uncompahgre Valley, about 5 miles east of the old location, would not be a shorter and better line. In a report dated February 6, 1904, Mr. McConnell reported that it had been definitely determined that the new location was considerably shorter and more practicable than the older one. Further investigations demonstrated this even more clearly, and all work after that time, with reference to the location of the proposed tunnel, has been devoted to the new line, or, as it is usually called, the upper location.

On May 9, a consulting board, consisting of Arthur P. Davis, George Y. Wisner, and W. H. Sanders, accompanied and advised by Morris Bien, engineer, and L. G. Carpenter, State engineer of Colorado, met with the district and resident engineers at Montrose, Colo., considered the report of the district engineer, and visited the proposed tunnel locations. The upper location was then officially approved and the report of the district engineer was adopted, with minor modifications.

The report of the consulting engineers, accompanied by the detailed report of the district engineer, was forwarded to the chief engineer on May 13.

Since that time surveys have been carried on along the proposed tunnel line for the purpose of determining exactly the proper elevations at the river portal and Cedar Creek ends and the proper alignment. These surveys, requiring the most delicate instrumental work, are still in progress, but they have been brought to such a satisfactory stage that construction work upon the tunnel may be commenced at any time.

Tabulation of bids, Gunnison tunnel.

Class of work.	Taylor Moore Construction Co., Hillsboro, Tex.	Lusk & McClurg, Denver, Colo.	W. C. Bradbury, 55 Railroad Building, Denver, Colo.	Lantry Sharp Contracting Co., Gumbel Building, Kansas City, Mo.	Utah Construction Co., Ogden, Utah.	San Francisco Construction Co., 26 Montgomery street, San Francisco, Cal.	Orman & Crook, Pueblo, Colo.	Ferguson Contracting Co., Virginia and Kearsarge streets, Pittsburg, Pa.	J. H. Flick, 225 N. Y. Life Building, Kansas City, Mo.	John McKechney & Co., 288 E. Ohio street, Chicago, Ill.
Approach Cedar Creek portal cut.										
Excavation:										
Class 1, 75,000 cubic yards .... per cubic yard..	$0.16	$0.18	$0.16	$0.30	$0.16	$0.27	$0.28	$0.25	$0.35	$0.35
Class 2, 15,000 cubic yards .... do....	.23	.35	.35	.45	.35	.43	.40	.30	.62	.45
Class 3, 5,000 cubic yards .... do....	.30	.45	.40	.65	.45	.60	.50	.40	.90	.60
Class 4, 25,000 cubic yards .... do....	.75	.75	.85	.85	.75	.70	.90	.80	1.22	1.55
Riprap (in place), 1,000 cubic yards .... do....	3.00	1.00	1.00	1.50	1.25	4.00	3.00	6.00	1.50	2.00
Paving (in place), 2,000 square feet .... per square foot..	.20	.15	.12	.25	.15	.15	.15	.50	.43	.30
Concrete lining and portal masonry, 2,000 cubic yards .... per cubic yard..	6.75	8.00	7.00	10.00	8.00	7.50	8.00	10.00	17.00	7.00
Tunnel.										
Class 1, 10,000 linear feet .... per linear foot..	34.14	39.50	43.00	57.00	50.00	52.00	49.00	55.00	62.02	73.48
Class 2, 5,000 linear feet .... do....	35.10	41.90	45.00	55.00	54.00	57.00	58.00	61.00	68.00	73.76
Class 3, 11,000 linear feet .... do....	26.60	45.50	46.00	46.00	57.00	53.50	59.00	63.00	71.99	74.46
Class 4, 4,000 linear feet .... do....	36.60	65.00	57.50	48.33	60.00	62.00	77.00	99.00	96.12	97.52
Pumping 1,000 gallons per day of 24 hours:										
15-foot lift or less	.20	1.00	.03	.10	.25	.50	.50	2.50	.08	.10
More than 15-foot lift	.55	1.25	.05	.15	.85	.75	.75	3.00	.15	.15

On July 10 a consulting board, consisting of W. H. Sanders, George Y. Wisner, and J. H. Quinton, again met at Montrose and, with the district and resident engineers, prepared plans and specifications for the main tunnel. Bids were opened at Montrose on October 5 by the same consulting board, acting with the district engineer. Ten bids were received, the summation of which is shown in the table on page 204. The lowest bid, that by the Taylor-Moore Construction Company, of Hillsboro, Tex., was accepted. The specifications require that it shall be completed by April 15, 1908. The cost is expected to be about $1,000,000.

The tunnel, if constructed in accordance with the specifications, will be approximately 30,000 feet in length and 10½ by 11½ feet in cross section, with a fall of 2 feet in 1,000, and will have a carrying capacity of 1,300 second-feet. It is to be lined throughout, the lining varying with the different classes of rock passed through. The details of the tunnel are shown on Pl. XVIII.

SOUTH CANAL.

During the winter of 1903-4 a number of paper locations were made of the proposed South canal line, this being the line intended for the conveyance of water from Gunnison tunnel to Uncompahgre River on the southeast side of Uncompahgre Valley. After a number of trial lines had been run a location was fixed upon and report made to the consulting board that convened at Montrose on July 10. On July 13 this board recommended to the chief engineer the acceptance of the location and advertisement for bids upon the earthwork of approximately the first 9 miles of canal, containing about 480,000 yards of material. Bids were advertised for and were opened on September 15 by a consulting board, consisting of W. H. Sanders, J. H. Quinton, and A. L. Fellows. A schedule of the bids is given on pages 206 and 207. The bid of Kellogg & Worley, of Gunnison, Colo., was the lowest on section 6; that of Knowlton & Bollen, of Fort Collins, Colo., was the lowest on sections 1, 2, 7, 8, and 9; and that of Orman & Crook, of Pueblo, Colo , was the lowest on sections 3, 4, and 5. The board therefore recommended that contracts for these sections be let to the lowest bidders. On October 18 these bids were officially accepted and contracts forwarded to the successful bidders for signature.

This canal, if constructed in accordance with the specifications, will, when completed, be capable of carrying approximately 1,300 second-feet from Gunnison tunnel to Uncompahgre River. The bottom width will vary from 10 feet in certain sections lined with concrete to 40 feet in the more level and open country. The average depth will be nearly 10 feet.

The specifications require that the canal shall be completed within one year from the time of commencing work. The total cost for the excavation will be approximately $80,000.

Edward E. Sands, assistant engineer, has had charge of the location work along this canal line.

Tabulation of bids, South canal, Uncompahgre Valley project.

Excavation.	Kellogg & Worley, Gunnison, Colo.	Knowlton & Bollen Construction Co., Fort Collins, Colo.	Orman & Crook, Pueblo, Colo.	Taylor-Moore Construction Co., Hillsboro, Tex.	Bell & Levy, Pueblo, Colo.	Galbraith & Co., South Fork, Colo.	W. C. Whitescarver, Trinidad, Colo.	Lowther Sproule, Montrose, Colo.	Hoover & Lake, Durango, Colo.	Carson Wells, Denver, Colo.	Dillon & Jones, Montrose, Colo.	Smith Bros., Montrose, Colo.
Section 1:												
Class 1, 11,000 cubic yards .... per cubic yard..	....	$0.12	$0.14	$0.13¼	$0.15	....	....	....	....	....	....	....
Class 2, 8,000 cubic yards .... do....	....	.28	.25	.27	.35	....	....	....	....	....	....	....
Class 3, 2,000 cubic yards .... do....	....	.34	.35	.32	.37	....	....	....	....	....	....	....
Class 4 .... do....	....	.95	....	....	.75	....	....	....	....	....	....	....
Overhaul, 4,500 cubic yards .... do....	....	.01⅕	.01⅛	.01¾	.01	....	....	....	....	....	....	....
Section 2:												
Class 1, 22,000 cubic yards .... do....	$0.13	.12	.14	.15¼	.15	....	....	....	....	....	$0.20	....
Class 2, 11,073 cubic yards .... do....	.20	.28	.25	.27	.35	....	....	....	....	....	.75	....
Class 3, 2,000 cubic yards .... do....	.65	.34	.35	.32	.37	....	....	....	....	....	.90	....
Class 4 .... do....	1.25	.95	....	....	.75	....	....	....	....	....	1.00	....
Overhaul, 2,000 cubic yards .... do....	.06	.01⅕	.01⅛	.01¾	.01	....	....	....	....	....	.04	....
Section 3:												
Class 1, 26,000 cubic yards .... do....	....	.13	.14	.15	.15	$0.19	....	....	$0.18	....	....	....
Class 2, 12,000 cubic yards .... do....	....	.28	.25	.27	.35	.60	....	....	.38	....	....	....
Class 3, 6,000 cubic yards .... do....	....	.34	.35	.32	.37	.40	....	....	.40	....	....	....
Class 4 .... do....	....	.95	....	....	.75	....	....	....	.85	....	....	....
Overhaul, 18,000 cubic yards .... do....	....	.01⅕	.01⅛	.01¾	.01	.02	....	....	.01⅛	....	....	....
Section 4:												
Class 1, 27,000 cubic yards .... do....	....	.13	.14	.16	.15	.19	....	....	.18	....	....	....
Class 2, 12,000 cubic yards .... do....	....	.28	.25	.27	.35	.60	....	....	.38	....	....	....
Class 3, 7,000 cubic yards .... do....	....	.34	.35	.32	.37	.40	....	....	.40	....	....	....
Class 4 .... do....	....	.95	....	....	.75	....	....	....	.85	....	....	....
Overhaul, 27,000 cubic yards .... do....	....	.01⅕	.01⅛	.02	.01	.02	....	....	.01⅛	....	....	....

Section 5:													
Class 1, 24,000 cubic yards	do	.14	.13	.14	.17	....	.19	....	....	.17	$0.15	....	....
Class 2, 15,000 cubic yards	do	.21	.28	.25	.28	....	.60	....	....	.39	.35	....	....
Class 3, 7,500 cubic yards	do	.65	.34	.35	.33	....	.40	....	....	.40	.35	....	....
Class 4	do	1.25	.95	....	....	....	....	....	....	.85	.75	....	....
Overhaul, 27,000 cubic yards	do	.05	.01½	.01½	.02	....	.02	....	....	.01½	.01	....	....
Section 6:													
Class 1, 46,000 cubic yards	do	.11	.13	.14	.13	....	.17	$0.12½	$0.15	....	.15	....	$0.18
Class 2, 6,000 cubic yards	do	.15	.28	.25	.25	....	.60	.30	.50	....	.35	....	.48
Class 3, 2,000 cubic yards	do	.50	.34	.35	.31	....	.40	.45	1.00	....	.35	....	.75
Class 4	do	1.25	.95	....	....	....	....	....	1.25	....	.75	....	....
Overhaul, 2,000 cubic yards	do	.05	.01½	.01½	.01¾	....	.02	.1½	.02	....	.01	....	.08
Section 7:													
Class 1, 45,000 cubic yards	do	....	.12	.14	.13	....	....	.12½	.15	....	....	....	.16¾
Class 2, 5,000 cubic yards	do	....	.28	.25	.25	....	....	.30	.50	....	....	....	.48
Class 3, 2,000 cubic yards	do	....	.34	.35	.31	....	....	.45	1.00	....	....	....	.75
Class 4	do	....	.95	....	....	....	....	....	1.25	....	....	....	....
Overhaul, 2,000 cubic yards	do	....	.01½	.01½	.01¾	....	....	.01½	.02	....	....	....	.08
Section 8:													
Class 1, 48,000 cubic yards	do	....	.12	.14	.13	....	....	.12½	.15	....	....	....	.18
Class 2, 5,000 cubic yards	do	....	.28	.25	.25	....	....	.30	.50	....	....	....	.48
Class 3, 2,000 cubic yards	do	....	.34	.35	.31	....	....	.45	1.00	....	....	....	.75
Class 4	do	....	.95	....	....	....	....	....	1.25	....	....	....	....
Overhaul 2,000 cubic yards	do	....	.01½	.01½	.01¾	....	....	.01½	.02	....	....	....	.08
Section 9:													
Class 1, 45,000 cubic yards	do	....	.12	.14	.14	....	....	.15	....	....	....	....	....
Class 2, 10,000 cubic yards	do	....	.28	.25	.26	....	....	.35	....	....	....	....	....
Class 3, 5,000 cubic yards	do	....	.34	.35	.32	....	....	.45	....	....	....	....	....
Class 4	do	....	.95	....	....	....	....	....	....	....	....	....	....
Overhaul, 2,000 cubic yards	do	....	.01½	.01½	.01¾	....	....	.01½	....	....	....	....	....

EAST CANAL.

During the winter of 1903–4 a number of paper locations were made for a proposed canal line to convey water from the east end of Gunnison tunnel, or from some point on Uncompahgre River, to irrigate the lands in the eastern portion of Uncompahgre Valley. A number of trial lines were run during the summer of 1904, and a large portion of the proposed east canal is now definitely located.

The work of making designs for structures upon this canal and the final location of the lower end of the canal is still under way, but it is expected that the plans and specifications will be ready in the near future.

Charles T. Pease, engineer, has been in direct charge of this work during the past season.

WEST CANAL.

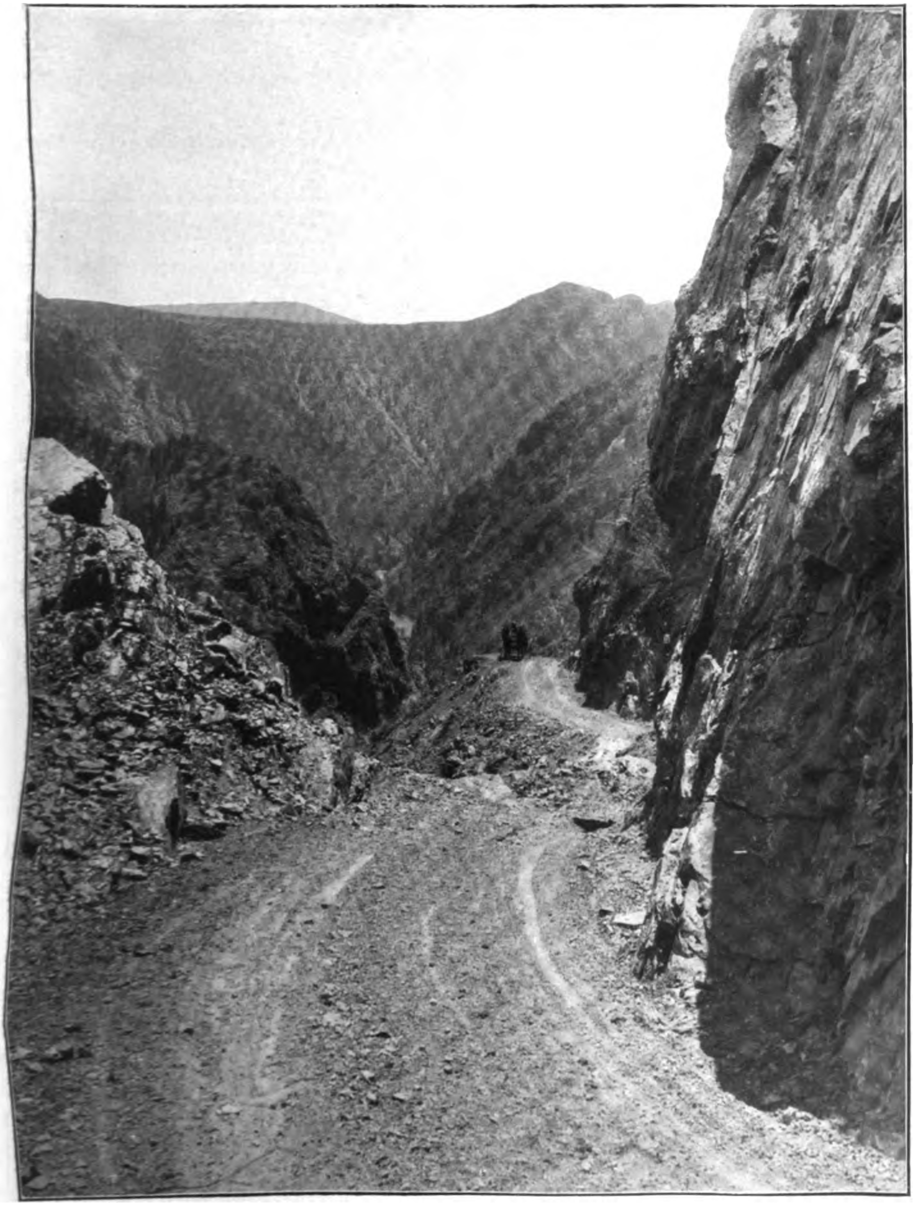
Since the completion of the topographic work in the northern and western portions of Uncompahgre Valley, a number of paper locations have been made and trial lines run for the purpose of determining the best location for a line, approximately 40 miles in length, for the purpose of conveying water from Uncompahgre River, starting at or near the point from which water will discharge into Uncompahgre River from the south canal, and running in a northwesterly direction to Roubideau Creek, in the northwestern corner of the district to be irrigated. A line has finally been determined upon for a considerable portion of the distance and location stakes have been set.

It is expected that plans and specifications will be ready for advertisement on this canal in the spring of 1905.

Edward E. Sands and J. T. Keenan, assistant engineers, have had charge of the location work along this canal line.

TUNNEL ROAD.

As soon as the location of the tunnel line had been definitely decided, surveys were made with reference to the construction of a wagon road to connect the two ends of the proposed tunnel, one end being near Cedar Creek station on the Denver and Rio Grande Railroad, and the other being in Gunnison Canyon, about 6 miles distant in a straight line and about 10 miles by the grade. Several lines were surveyed and one was definitely selected. In order that there might be no delay through advertisement and the letting of a contract, it was decided that the Government should itself build this road. Accordingly, a force of men was placed in the field, under the direction of A. F. Ross and W. J. Lightfoot, and on October 1 the road was practically completed, except for the necessity of providing a few additional turnouts and widening the road at a number of places (see Pl. XIX).



VIEW OF PORTION OF COMPLETED TUNNEL ROAD, UNCOMPAHGRE VALLEY PROJECT, COLORADO.

Going from the Cedar Creek end of the road up the Vernal Mesa, over which the road passes, the steepest grade is 5.8 per cent. After passing the summit and going down into the canyon, the grade increases from 1 per cent at the upper end to about 23 per cent in places toward the lower end, the heavy grade being rendered necessary by the character of the country and being permissible from the fact that it is not expected that loads will ever be hauled out from the canyon, but that all will be taken into it. The road will be of permanent value, as it will be needed in the maintenance of the project in the future.

TELEPHONE SYSTEM.

For the purpose of facilitating the work of construction of the proposed irrigating system, it was determined that a telephone system should be built, extending at first from Montrose to the two ends of the tunnel, and also covering the south-canal location.

Specifications were drawn up by H. A. Storrs, electrical engineer, and advertisement for bids made, and opened on September 22; a schedule is shown herewith. E. A. Hess, of Lyons, Iowa, was the lowest bidder, and the contract was awarded to him on October 18.

The telephone system will be needed not only during the period of construction, but also throughout the future for the maintenance of the irrigation system.

Proposals for the construction of a telephone system, Uncompahgre Valley project, Colorado.

POLE LINE FOR SECTION 1.

[Approximate length, 9¼ miles.]

Number, name, and address of bidders.	Cost per mile.	Estimated cost of line.	Time of completion.
1. E. A. Hess, Lyons, Iowa[a]	$214.11	$1,980.50	Begins work within 30 days after notification of execution of contract, and will complete work on or before 30 days from the execution of contract.
2. Builders' Contracting Co. (by K. C. Shurick, president), 821 Chestnut street, St. Louis, Mo.[b]	411.00	3,801.75	Begins work within 6 days after date of notification of execution of contract, and will complete work on or before the 35th day from date of execution of contract.
3. Silver State Electric Co. (Robt. S. Willoughby), 214 Fifteenth street, Denver, Colo.[c]	260.00	2,405.00	Begins work within 30 days after date of notification of execution of contract, and will complete work on or before 70 days.
4. Jas. R. Thorpe, Denver, Colo.[d]	374.25	3,461.81	Begins work within 10 days after date of notification of execution of contract, and will complete work on or before 30 days.

[a] Telephones, arresters, cells, and insulators manufactured by the Kellogg Switchboard and Supply Co. Wire by the Roebling or American Steel and Wire Co. Amount of check submitted with proposal, $124.24.

[b] Telephones, arresters, cells, etc., manufactured by the Deyeau Telephone Manufacturing Co. Wire by the Roebling or American Steel and Wire Co. Amount of check submitted, $320.

[c] Amount of check submitted with proposal, $150. Proposal covering the entire system as defined by the entire specifications, in amount $7,400. The work to be commenced within 30 days after receipt of notification of acceptance, and completed within 70 days thereafter, in complete working order.

[d] Bids on all eight items are based upon the award of the entire contract, and are not valid for single items. Amount of check submitted with proposal, $206.40. Supplementary proposal: A reduction of $1.50 per pole from contract price for each iron pole substituted for wooden pole specified. Further proposes to install loop station equipments at $17 each. (See supplementary proposal.)

Proposals for the construction of a telephone system, etc.—Continued.

POLE LINE FOR SECTION 2.

[Approximate length, 10 miles.]

Number, name, and address of bidder.	Cost per mile.	Estimated cost of line.	Time of completion.
1. E. A. Hess, Lyons, Iowa[a]	$214.80	$2,148.00	Begins work within 30 days after date of notification of execution of contract, and will complete work on or before 60 days from execution of contract.
2. Builders' Contracting Co. (by K. C. Shurick, president), 821 Chestnut street, St. Louis, Mo.[b]	451.00	4,510.00	Begins work within 10 days after date of notification of execution of contract, and will complete work on or before the thirty-fifth day from date of execution of contract.
3. Silver State Electric Co. (Robt. S. Willoughby), 214 Fifteenth street, Denver, Colo.[c]	260.00	2,600.00	Begins work within 30 days after date of notification of execution of contract, and will complete work on or before 70 days.
4. Jas. R. Thorpe, Denver, Colo.[d]	392.25	3,922.50	Begins work within 30 days after date of notification of execution of contract, and will complete work on or before 45 days.

POLE LINE FOR SECTION 3.

[Approximate length, 7½ miles.]

1. E. A. Hess, Lyons, Iowa[a]	$242.56	$1,819.20	Begins work within 30 days after date of notification of execution of contract, and will complete work on or before 45 days from execution of contract.
2. Builders' Contracting Co. (by K. C. Shurick, president), 821 Chestnut street, St. Louis, Mo.[b]	490.00	3,675.00	Begins work within 6 days after date of notification of execution of contract, and will complete work on or before the 35th day from date of execution of contract.
3. Silver State Electric Co. (Robt. S. Willoughby), 214 Fifteenth street, Denver, Colo.[c]	260.00	1,950.00	Begins work within 30 days after date of notification of execution of contract, and will complete work on or before 70 days.
4. Jas. R. Thorpe, Denver, Colo.[d]	424.48	3,183.60	Begins work within 20 days after date of notification of execution of contract, and will complete work on or before 30 days.

POLE LINE FOR SECTION 4.

[Approximate length, 1 mile.]

1. E. A. Hess, Lyons, Iowa[a]	$264.50	$264.50	Begins work within 40 days after date of notification of execution of contract, and will complete work on or before 45 days from execution of contract.
2. Builders' Contracting Co. (by K. C. Shurick, president), 821 Chestnut street, St. Louis, Mo.[b]	[a]553.00	553.00	Begins work within 10 days after date of notification of execution of contract, and will complete work on or before the 35th day from date of execution of contract.
3. Silver State Electric Co. (Robt. S. Willoughby), 214 Fifteenth street, Denver, Colo.[c]	[a]500.00	500.00	Begins work within 30 days after date of notification of execution of contract, and will complete work on or before 70 days.
4. Jas. R. Thorpe, Denver, Colo.[d]	[a]543.50	543.50	Begins work within 40 days after date of notification of execution of contract, and will complete work on or before 45 days.

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[a] Telephones, arresters, cells, and insulators manufactured by the Kellogg Switchboard and Supply Co. Wire by the Roebling or American Steel and Wire Co. Amount of check submitted with proposal, $124.24.

[b] Telephones, arresters, cells, etc., manufactured by the Deyeau Telephone Manufacturing Co. Wire by the Roebling or American Steel and Wire Co. Amount of check submitted, $320.

[c] Amount of check submitted with proposal, $150. Proposal covering the entire system as defined by the entire specifications, in amount $7,400. The work to be commenced within 30 days after receipt of notification of acceptance, and completed within 70 days thereafter, in complete working order.

[d] Bids on all eight items are based upon the award of the entire contract, and are not valid for single items. Amount of check submitted with proposal, $206.40. Supplementary proposal: A reduction of $1.50 per pole from contract price for each iron pole substituted for wooden pole specified. Further proposes to install loop station equipments at $17 each. (See supplementary proposal.)

Proposals for the construction of a telephone system, etc.—Continued.

TELEPHONE APPARATUS FOR SECTION 1.

Number, name, and address of bidder.	Cost per mile.	Time of completion.
1. E. A. Hess, Lyons, Iowa[a]	$80.00	Begins work within 3 days after line is ready for the apparatus, or after receipt of notice thereof, if line is installed by another contractor, and will complete the same within 3 days after that date.
2. Builders' Contracting Co. (by K. C. Shurick, president), 821 Chestnut street, St. Louis, Mo.[b]	210.00	Begins work within 5 days after line is ready for the apparatus, or after receipt of notice thereof, if line is installed by another contractor, and will complete work within 5 days after that date.
3. Silver State Electric Co. (Robt. S. Willoughby), 214 Fifteenth street, Denver, Colo.[c]	200.00	Begins work within 30 days after line is ready for the apparatus, or after receipt of notice thereof, if line is installed by another contractor, and will complete work within 70 days after that date.
4. Jas. R. Thorpe, Denver, Colo.[d]	93.30	Begins work within 2 days after line is ready for the apparatus, and will complete the same within 5 days after that date.

TELEPHONE APPARATUS FOR SECTION 2.

1. E. A. Hess, Lyons, Iowa[a]	$48.00	Begins work within 3 days after line is ready for the apparatus, or after receipt of notice thereof, if line is installed by another contractor, and will complete the same within 3 days after that date.
2. Builders' Contracting Co. (by K. C. Shurick, president), 821 Chestnut street, St. Louis, Mo.[b]	130.00	Begins work within 5 days after line is ready for the apparatus, or after receipt of notice thereof, if line is installed by another contractor, and will complete the same within 5 days after that date.
3. Silver State Electric Co. (Robt. S. Willoughby), 214 Fifteenth street, Denver, Colo.[c]	200.00	Begins works within 30 days after line is ready for the apparatus, or after receipt of notice thereof, if line is installed by another contractor, and will complete the same within 70 days after that date.
4. Jas. R. Thorpe, Denver, Colo.[d]	84.30	Begins work within 2 days after line is ready for the apparatus, and will complete the same within 5 days after that date.

TELEPHONE APPARATUS FOR SECTION 3.

1. E. A. Hess, Lyons, Iowa[a]	$24.00	Begins work within 3 days after line is ready for the apparatus, or after receipt of notice thereof, if line is installed by another contractor, and will complete the same within 5 days after that date.
2. Builders' Contracting Co. (by K. C. Shurick, president), 821 Chestnut street, St. Louis, Mo.[b]	65.00	Begins work within 5 days after line is ready for the apparatus, or after receipt of notice thereof, if line is installed by another contractor, and will complete the same within 5 days after that date.
3. Silver State Electric Co. (Robt. S. Willoughby), 214 Fifteenth street, Denver, Colo.[c]	200.00	Begins work within 30 days after line is ready for the apparatus, or after receipt of notice thereof, if line is installed by another contractor, and will complete the same within 70 days after that date.
4. Jas. R. Thorpe, Denver, Colo.[d]	36.20	Begins work within 2 days after line is ready for the apparatus, and will complete the same within 5 days after that date.

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[a] Telephones, arresters, cells, and insulators manufactured by the Kellogg Switchboard and Supply Co. Wire by the Roebling or American Steel and Wire Co. Amount of check submitted with proposal, $124.24.

[b] Telephones, arresters, cells, etc., manufactured by the Deyeau Telephone Manufacturing Co. Wire by the Roebling or American Steel and Wire Co. Amount of check submitted, $320.

[c] Amount of check submitted with proposal, $150. Proposal covering the entire system as defined by the entire specifications, in amount $7,400. The work to be commenced within 30 days after receipt of notification of acceptance, and completed within 70 days thereafter, in complete working order.

[d] Bids on all eight items are based upon the award of the entire contract, and are not valid for single items. Amount of check submitted with proposal, $206.40. Supplementary proposal: A reduction of $1.50 per pole from contract price for each iron pole substituted for wooden pole specified. Further proposes to install loop station equipments at $17 each. (See supplementary proposal.)

Proposals for the construction of a telephone system, etc.—Continued.

TELEPHONE APPARATUS FOR SECTION 4.

Number, name, and address of bidders.	Cost per mile.	Time of completion.
1. E. A. Hess, Lyons, Iowa[a]	$20.00	Begins work within 3 days after line is ready for the apparatus, or after receipt of notice thereof, if line is installed by another contractor, and will complete the same within 3 days after that date.
2. Builders' Contracting Co. (by K. C. Shurick, president), 821 Chestnut street, St. Louis, Mo.[b]	60.00	Begins work within 5 days after line is ready for the apparatus, or after receipt of notice thereof, if line is installed by another contractor, and will complete the same within 5 days after that date.
3. Silver State Electric Co. (Robt. S. Willoughby), 214 Fifteenth street, Denver, Colo.[c]	200.00	Begins work within 30 days after line is ready for the apparatus, or after receipt of notice thereof, if line is installed by another contractor, and will complete the same within 70 days after that date.
4. Jas. R. Thorpe, Denver, Colo.[d]	22.95	Begins work within 2 days after line is ready for the apparatus, and will complete the same within 5 days after that date.

[a] Telephones, arresters, cells, and insulators manufactured by the Kellogg Switchboard and Supply Co. Wire by the Roebling or American Steel and Wire Co. Amount of check submitted with proposal, $124.24.

[b] Telephones, arresters, cells, etc., manufactured by the Deyeau Telephone Manufacturing Co. Wire by the Roebling or American Steel and Wire Co. Amount of check submitted, $320.

[c] Amount of check submitted with proposal, $150. Proposal covering the entire system as defined by the entire specifications, in amount, $7,400. The work to be commenced within 30 days after receipt of notification of acceptance, and completed within 70 days thereafter, in complete working order.

[d] Bids on all eight items are based upon the award of the entire contract, and are not valid for single items. Amount of check submitted with proposal, $206.40. Supplementary proposal: A reduction of $1.50 per pole from contract price for each iron pole substituted for wooden pole specified. Further proposes to install loop station equipments at $17 each. (See supplementary proposal.)

RESERVOIR SITES.

Throughout the summer season reservoir surveys have been carried on under the immediate direction of J. M. Roberts, topographer, in charge of a plane-table party.

Four reservoir sites were surveyed on the headwaters of Gunnison River, these being (1) a site near Park Cone, at the lower end of Taylor Park, (2) a site near Dorchester, on the headwaters of Taylor River, (3) a site on East River, about 6 miles east of Crested Butte, and (4) a site on Cement Creek, a tributary of East River, about 6 miles southeast of the East River site. The capacities of these sites have not yet been calculated, but two of them at least are believed to be feasible for storage at reasonable cost.

DRAINAGE SYSTEM.

To the end that the best possible use might be made of the water supply furnished Uncompahgre Valley, a study is being made of drainage possibilities in connection with location of canals. It is thought that a considerable portion of the water can be saved and used over to better advantage by constructing certain drainage canals than by letting the water go to waste or flow into natural drainage channels.

These investigations are still being carried on and no report has as yet been made with reference to them.

The principal necessity for drainage will be on the east side of the valley, and it is believed that here considerable drainage will be necessary to insure the most economical and satisfactory use of the water.

FORESTATION.

During the month of January, 1904, an investigation was made of the forest conditions on the headwaters of East River and other tributaries of Gunnison River in Gunnison County. It was found that the hills had been almost entirely denuded of their timber supply in many localities, and strong recommendations were made asking that forest reserves be established on the headwaters of Gunnison River for the purpose of conserving the water supply for the benefit of irrigation.

In accordance with these recommendations temporary withdrawals have been made, but no permanent reserves have yet been established.

HYDROGRAPHY.

Hydrographic investigations have been made throughout the year with a view to furnishing definite information concerning the water supply.

Gaging stations have been maintained at Eldredge, Montrose, and Delta on Uncompahgre River; Cimarron, Cory, and Whitewater on Gunnison River; Hotchkiss on North Fork of Gunnison River; and Cimarron on Cimarron River. Frequent gagings have also been made at Summerville Park on Taylor River, and at Almont on East River, these measurements being made for the purpose of determining the amount of water available for storage. Numerous miscellaneous measurements have also been made upon the canals in Uncompahgre Valley and the small streams, usually dry, but sometimes carrying large bodies of water, in the same locality. Seepage investigations have also been made. Tables giving the data in intelligible form, however, have not as yet been compiled. They will be included in the water-supply paper covering hydrographic investigations for 1904.

CLASSIFICATION OF LANDS AND STUDY OF SOILS.

During the latter part of the season studies have been made of the character of the soils of the public lands under the proposed irrigation system, these investigations being carried on under the direction of Thomas H. Means, soil expert.

The studies have been practically completed, covering the entire body of land in public ownership under the proposed system, but a report concerning the same has not as yet been rendered. Upon receipt of the report, the lands in public ownership will be classified and subdivided into farm units, after which maps covering these features will be sent to the General Land Office.

HEADQUARTERS.

Owing to the fact that the town of Montrose is most centrally located with reference to almost the entire proposed reclamation project, it was found desirable to establish permanent headquarters at that place, not only for facilitating the work of construction, but also for convenience in meeting the water consumers under the reclamation project throughout its maintenance by the Government.

Accordingly a lot was purchased in the town for $450, on which a building costing about $5,000 will at once be erected. Temporary headquarters for surveying parties have also been established at the river portal and Cedar Creek ends of Gunnison tunnel, and at a point conveniently located with reference to the south canal.

At each of the first two above-named points log cabins are being erected for the use of the engineers, and at the third, tents, with board floors, have been provided, and frame buildings of rough boards put up for winter quarters.

MAPPING AND DESIGNING.

Throughout the entire year work has been done in the Montrose and Denver offices, on both mapping and designing.

Contour maps of Uncompahgre Valley have been made on the scale of 1 inch to 1 mile and 2 inches to 1 mile. The latter map has been photographed down to the scale of 1 inch to the mile, and also to the scale of one-quarter of an inch to the mile, the latter size being used for progress reports. A great many plats of sections of Uncompahgre Valley, showing locations of canal lines, have also been made.

A number of designs have been drawn and studied, covering not only the construction work on the tunnel and south canal, but also the tunnel headworks and various diverging gates, spillways, sluiceways, drops, and other structures connected with the canal system. None of these have as yet been approved, but it is expected that all will be ready to be submitted to the consulting board during the coming winter.

GEOLOGIC INVESTIGATIONS.

In May investigations were made by C. E. Siebenthal, assistant geologist, with a view to determining the probable formations to be passed through by the proposed tunnel.

Since September Mr. Siebenthal has been engaged in a more complete and thorough investigation of the geologic conditions of Uncompahgre Valley, with a view to determining the artesian possibilities of the region. His report has not yet been submitted.

UNCOMPAHGRE VALLEY WATER USERS' ASSOCIATION.

The Uncompahgre Valley Water Users' Association has kept up its organization throughout the year. On March 19 an election of officers was held and a partly new board of directors was elected, which made a report to the Secretary of the Interior in time for consideration at the meeting of the board of consulting engineers on May 9.

Two general meetings of the stockholders of the association were held at Olathe, on August 10 and September 14, for the purpose of voting upon certain proposed amendments to the articles of incorporation, which were suggested by Morris Bien. All the amendments proposed were finally adopted.

Owing to the efforts of the board, approximately 95,000 acres in private ownership were subscribed in form satisfactory to the consulting board before the closing of the books on August 15.

GRAND RIVER PROJECT.

A detailed report on this project was printed in the Second Annual Report of the Reclamation Service, pages 210 to 250. As there stated, private capital has been making an investigation with a view to construction, and, pending the result of the efforts of the promoters, nothing has been done by the Reclamation Service. An irrigation district was formed, directors were elected, and efforts made to negotiate the sale of bonds of the district. Recently, however, letters and petitions of citizens in the Grand Valley have been received, stating that it had been found impossible to negotiate the bonds, and the assistance of the Government has again been urged.

A meeting was held at Grand Junction on the evening of October 3, 1904, which was largely attended by the water consumers of the district, and resolutions were passed requesting the Government to construct the project and placing the matter in the hands of the officers of the irrigation district already incorporated, for the purpose of forming a water users' association and of conferring with the officers of the Reclamation Service regarding possible construction.

Since that time other meetings have been held, at which plans have been made with reference to the work necessary for the association to do, it being the design of the officers of the association to present to the Government a clear statement of the amount of land available and of the willingness of the people owning land under the proposed project to take water under the provisions of the reclamation act. No definite plans have as yet been submitted.

In accordance with recommendations made by the Director of the Geological Survey, under date of March 24, 1904, all lands previously withdrawn south of Grand River were restored to entry, this course having been requested by Senator Teller and Representative Hogg. The residents of this tract, however, appear to be unanimously desirous of entering a water users' association, should one be formed, and of becoming beneficiaries under the reclamation act.

No other changes were made in the lands withdrawn during the year.

WHITE RIVER PROJECT.

Since June 15, 1904, no surveys have been made in connection with the White River project, except some reconnaissances by Oro McDermith, assistant engineer, of the Lost Park and Fawn Creek sites, which have been suggested as feeders for the White River project.

Lost Park reservoir site is located in White River Forest Reserve, 5 miles north of the junction of Lost Creek with North Fork of White River, and about 6 miles from the gaging station on Marvine Creek. It covers approximately the SW. ¼ SW. ¼ sec. 2, S. ½ sec. 3, N. ½ sec. 10, and NW. ¼ NW. ¼ sec. 11, T. 1 N., R. 90 W. of the sixth principal meridian.

The rocks here are basalt and sandstone covered with earth 10 to 15 feet deep. There are shale outcrops on the eastern side. The rocks at the dam site are shale and sandstone.

The water supply is obtained from Lost Creek, which discharges from 6 or 7 second-feet at low-water periods to 100 second-feet at flood stages. These quantities are estimated, there being no data obtainable at the present time.

An earth dam 170 feet long at the bottom, 75 feet high, and 600 feet long at the top, would impound water over about 700 acres to an average depth of 40 feet. The capacity of the reservoir would be approximately 28,000 acre-feet. Good stone for riprap can be obtained within 1 mile.

The drainage basin consists in general of comparatively gentle slopes, covered with spruce and aspen forests. The water supply is mostly from melting snow. The area of the drainage basin is about 40 square miles.

The site is available as a means of storage for the White River project. It is located high in the mountains, where there is an abundance of snow. It would be of little value, however, unless used in connection with some large project.

Fawn Creek reservoir site is one-half mile north of Pattison's farmhouse and the road crossing of Fawn Creek in the White River Forest Reserve. It covers approximately the SE. ¼ SE. ¼ sec. 18 and NE. ¼ sec. 19, T. 1 N., R. 90 W. It is 200 feet north of and 10 feet higher than the proposed canal line of the White River project.

The water supply is uncertain. No data are available, but the flow is estimated as varying from 150 second-feet at high water to 6 or 7 second-feet during low-water periods. An average of from 20 to 30 second-feet during the summer season could probably be relied upon.

A dam 75 feet high, 25 feet long at the bottom, and 390 feet long at the top would cause an area approximately one-half mile long and 600 feet wide to be submerged to a depth of between 40 and 60 feet. A dam 50 feet high would cause about the same area to be covered with ter to a depth of between 20 and 40 feet.

The drainage basin consists of steep hills, covered with aspen and spruce forests. Its area is about 30 square miles.

The site is a small one, but could be used in connection with the White River project, or for the lands in Pothole Valley on upper White River. It is probably of no great importance.

From October 9 to 15, inclusive, the broader features of the White River project were studied by the district engineer.

The irrigable land appears to lie generally in tracts of from 1,000 to 3,000 acres each, many of them lying among the sand hills along the south side of Yampa River in Routt County. Deep ravines must be crossed in order to reach the most of these tracts, and the practicability of the project from a financial standpoint at the present time appears doubtful. Eventually, when land becomes more valuable in that region, construction may be feasible.

During the year a number of desert claims have been visited and reports made with reference to the granting of patents for them. In nearly all cases the applications have been approved, the requirements of the law having been practically complied with.

COLORADO RIVER STORAGE PROJECTS.

In connection with the studies which have been made with reference to the reclamation of large bodies of land along Colorado River in southern California and western Arizona, certain reservoir sites have been segregated in western Colorado, two of these being on Grand River in Grand County, and two being on Yampa River in Routt County. Reconnaissance examinations have been made on all of these sites, and detail surveys of those on Yampa River are being made at the present time.

KREMMLING RESERVOIR SITE.

This site is located in the western part of Grand County and has an area of about 14,000 acres at the 181-foot contour line. It has been estimated that its storage capacity is about 1,500,000 acre-feet. The lands covering this site, amounting to 39,680 acres, were segregated May 12, 1904.

No work except some of reconnaissance character has been carried on by the Reclamation Service in regard to this site, all of the data available being derived from surveys made by local capitalists interested in the development of power. It is not expected that surveys of the site will be made until claims made by rival companies have been settled.

GRAND LAKE.

This lake is located in the northeastern part of Grand County, Colo. It was withdrawn for examination on June 8, 1904, the area set apart being 23,040 acres, or one township.

No survey except a reconnaissance has been made of the lake. The land about its boundaries is practically all owned by private individuals, the district being a well-known pleasure resort.

YAMPA RESERVOIRS.

Two reservoir sites have been located on Yampa River in Routt County, and topographic surveys are being made of both. A reconnaissance survey has also been made of a third site.

On July 1, 1904, lands about these sites were withdrawn by order of the Secretary of the Interior, the area set apart being about 100,000 acres. The surveys of these sites not having been completed, no reports concerning them are available, but it is estimated that any one of the three sites can store all the surplus waters of Yampa River after permitting all possible irrigation in Colorado.

RECONNAISSANCE SURVEYS.

In addition to examinations and surveys which may lead to early construction, some expenditures have been incurred in looking after various projects of interest.

Exploration has been carried on in western Colorado and considerable time has been devoted to reports upon several projects in other parts of the State which have been popularly considered to be of importance. Among those of special interest, concerning which reports have been submitted, are the Rio Grande reservoir sites at Wagonwheel Gap and on the headwaters of the Rio Grande; possible irrigation of various tracts in eastern Colorado; a reconnaissance of North Park, Colorado, a detailed report concerning which was submitted by M. C. Hinderlider under date of June 7, 1904; and reports concerning numerous small projects scattered over various parts of the State.

DENVER OFFICE.

General administrative and supply headquarters have been maintained at Denver, which is also used as a disbursing point not only for Colorado, but for some of the adjacent States.

The office is under the general direction of A. L. Fellows, district engineer for Colorado, and is also used by H. A. Storrs, electrical engineer, J. E. Field, district engineer for Nebraska and eastern Wyoming, R. F. Walter, district engineer for South Dakota, and other engineers.

Eleven rooms are used at the present time, with a floor space of approximately 5,000 square feet. The office is provided with the usual furniture for drafting and correspondence, shelving for supplies, and arrangements for photographing and blueprinting. A consulting room is provided for the convenience of the board of consulting engineers. Throughout the winter of 1903–4, the office was occupied by a number of parties from outside the State, and it is expected that during the coming winter it will be used by still more parties.

The general expenses connected with the maintenance of the office have been charged up to the various projects.

OPERATIONS IN IDAHO.

By D. W. Ross.

During the field season of 1904 attention was concentrated mainly on the Minidoka project, owing to the fact that recommendation was made by a board of consulting engineers in favor of the immediate construction of this project by the Government.

During the winter of 1903–4 a great deal of interest was aroused in the Payette and Boise valleys in connection with the Payette-Boise project, and later on the landowners reported to the Secretary of the Interior the proceedings which had been taken by their organization committee. This report received favorable attention, and as a result the investigations begun the year before were resumed. The investigations begun in 1903 in the eastern part of the State in connection with the Dubois project, pointing to the feasibility of that enterprise, were also continued during the recent field season. These are the three principal projects in Idaho, and they provide for the reclamation of about 650,000 acres of desert land.

In addition to these investigations reconnaissance surveys were made of the smaller tributary valleys of the Snake River, and it is now believed that the irrigation possibilities of this great valley are pretty well known. Withdrawals of land have been recommended and made wherever it was thought that such a step would facilitate the carrying out of comprehensive plans and prevent conflicts from arising in the future.

Preliminary reports in detail of the three projects mentioned were published in the Second Annual Report of the Reclamation Service. The reports contain approximate estimates of cost based upon preliminary surveys. These figures have been revised wherever more definite surveys have been made. The field work on practically all the surveys will be completed very soon, and will furnish enough data for the preparation of approximate estimates, and in the case of the Payette-Boise project, for the designs of all the principal structures.

MINIDOKA PROJECT.

Preliminary investigations were made of this project during the field season of 1903. The nature of these investigations is fully explained in detail in the Second Annual Report of the Reclamation Service, pages 251–279. Stated briefly, they consisted of running trial lines on both sides of the river with a view of defining the dimensions of the project according to various plans under consideration, and ascertaining the general feasibility and approximate cost of the enterprise. A plane-table survey was made of the lands on the south side of the river to serve as a basis for designing the main features of the distributing system and classifying the lands. Pl. XX shows the distributing system and farm units and Pls. XXI–XXIII, show the plans for the dam and other works.

The general direction of the work in connection with this project has been in the charge of D. G. Martin, engineer. J. T. Burke, assistant engineer, has had general supervision of the plane-table work, and is now conducting surveys for the location of the distributing system. J. L. Savage, assistant engineer, has been engaged in the preparation of plans and drawings.

DAM, SPILLWAY, ETC.

Preliminary plans and estimates were prepared and definite recommendations made by the district engineer at the close of the season. These recommendations were referred to a project board which consisted of A. P. Davis, George Y. Wisner, and H. N. Savage, who met at Boise, March 21, and reported favorably on the project, recommending that it be undertaken by the Government; that $2,600,000 be set aside for the purpose, and that a contract be let at an early date for the construction of the first division of the work, to consist of the dam, spillway, forebay canal, and headgates, according to specifications prepared by them. Bids were invited, and were opened at Boise, Idaho, July 2, 1904. Seventeen bids were submitted, the lowest being that of Mr. N. J. Blagen, of Portland, Oreg. Mr. Blagen, however, failed to qualify under the terms of the specifications and, on August 22, 1904, a contract was entered into with the second lowest bidder, the Bates-Rogers Construction Company, of Chicago.

The following is an abstract of the proposals:

Abstract of proposals for Minidoka project.

	P. McDonnell, Duluth, Minn.	W. C. Bradbury, Denver, Colo.	Bates-Rogers Construction Co., Chicago, Ill.	Niels J. Blagen, Portland, Oreg.	Pacific Coast Construction Co., Portland, Oreg.	Fari-Kesl Construction Co., Boise, Idaho.	Grant, Smith & Co., Seattle, Wash.	Porter Bros., Spokane, Wash.
Excavating diversion channel:								
100 cubic yards, class 1	$0.40	$0.20	$0.15	$0.20	$0.30	$0.17½	$0.25	$0.25
100 cubic yards, class 2	.75	.50	.40	.45	.40	.35	.40	.45
1,000 cubic yards, class 3	.75	.55	.65	.45	.50	.65	.60	.65
40,000 cubic yards, class 4	1.50	1.48	.90	1.00	1.90	1.75	1.60	1.30
Excavating canal and foundation of spillways:								
43,000 cubic yards, class 1	.30	.22	.15	.10	.16	.17½	.25	.28
100 cubic yards, class 2	.75	.40	.40	.45	.40	.35	.40	.40
1,000 cubic yards, class 3	.75	.40	.65	.45	.50	.65	.60	.65
120,000 cubic yards, class 4	1.25	1.59	.70	.80	1.00	1.75	1.25	1.30
Overhaul:								
Above 200 feet	.02	.01½	.01½	.01	.02	.01½	.01¼	.01
Riprap in canal, 800 square yards	.50	1.00	1.25	1.00	.75	1.00	1.75	.50
Placing material in dam:								
110,000 cubic yards rock	.50	.50	.90	.95	.75	.95	.75	.50
101,000 cubic yards earth	.40	.80	.80	.35	.40	.42½	.50	.55
1,200 square yards riprap	.75	1.07	2.00	1.00	.75	1.00	1.75	.75
1,000 cubic yards concrete core wall	10.00	4.32	6.00	6.00	14.00	7.00	7.00	8.00
500 cubic yards excavation in foundation	3.00	3.50	3.00	3.50	5.00	4.00	2.00	8.00
Spillways:								
3,000 cubic yards concrete	5.00	4.32	5.00	5.50	6.00	6.00	6.00	6.00
8,000 cubic yards rock in embankments	1.25	1.15	.75	1.20	1.00	1.50	.75	1.50
7,200 cubic yards earth and gravel in embankments	.40	.22½	.50	.35	.25	.42½	.30	.45
6,500 cubic yards concrete in canal	4.50	4.50	7.00	5.80	8.00	6.00	7.00	8.00
3,000 pounds steel in same	.12	.06¼	.08	.07	.06	.08	.07	.08
57,500 pounds gates and guides for power and irrigation canals	.12	.10	.14	.12	.11	.12½	.12	.11¼

Abstract of proposals for Minidoka project—Continued.

	P. McDonnell, Duluth, Minn.	W. C. Bradbury, Denver, Colo.	Bates-Rogers Construction Co., Chicago, Ill.	Niels J. Blagen, Portland, Oreg.	Pacific Coast Construction Co., Portland, Oreg.	Fari-Kesl Construction Co., Boise, Idaho.	Grant, Smith & Co., Seattle, Wash.	Porter Bros., Spokane, Wash.
Spillways—Continued.								
14 pedestals and screw stems (Coffin ball bearing)	$500.00	$250.00	$300.00	$300.00	$243.50	$288.00	$300.00	$271.00
56 flash boards, 3 by 12 inches, bound with ¼ by 3 inch strap iron	5.00	3.00	3.00	3.00	5.00	1.25	3.50	1.50
4,500 pounds steel, 7-inch I-beams for pedestal supports with anchors	.12	.07½	.08	.07	.08	.08	.07	.08
720 cubic yards concrete dam in diversion channel	6.00	4.82	8.00	6.50	8.00	6.00	7.00	7.00
5 gates and guides for diversion channel (96 by 144 inch Coffin rectangular gates with rising screws and ball-bearing standards complete)	4,000.00	3,600.00	3,700.00	3,300.00	3,000.00	3,600.00	2,900.00	3,475.00
Total	429,329.00	488,914.00	425,923.00	390,203.00	456,004.00	553,159.00	473,576.00	464,045.00

	Mahoney Bros., Salt Lake City, Utah.	E. B. & A. L. Stone Co., Oakland, Cal.	Kilpatrick Bros. & Collins, Beatrice, Nebr.	American-Hawaiian Engineering and Construction Co., San Francisco.	Puget Sound Bridge and Dredging Co., Seattle, Wash.	Pendergrast & Clarkson, Chicago, Ill.	Utah Construction Co., Ogden, Utah.	Slick & Jensen, Salt Lake City, Utah.	Donald Grant & Co., Faribault, Minn.
Excavating diversion channel:									
100 cubic yards, class 1	$1.00	$0.50	$0.23	$0.60	$0.44	$0.30	$0.25	$0.30	$0.15
100 cubic yards, class 2	1.00	.75	.35	.94	.74	.60	.50	.75	.25
1,000 cubic yards, class 3	1.00	1.00	.55	1.00	.80	.95	1.00	1.00	.45
40,000 cubic yards, class 4	1.75	1.00	1.25	1.80	1.75	1.85	1.25	1.85	1.45
Excavating canal and foundation of spillways:									
43,000 cubic yards, class 1	.30	.50	.23	.60	.30	.22	.20	.21	.23
100 cubic yards, class 2	1.00	.75	.35	.94	.74	.60	.40	.75	.35
1,000 cubic yards, class 3	1.00	1.00	.55	1.00	.80	.95	.75	1.00	.45
120,000 cubic yards, class 4	1.20	1.00	1.25	1.45	1.40	1.85	1.25	1.00	1.85

Overhaul:									
Above 200 feet	.02	.03	.03	.02	.03	.02	.01½	.01	.02
Riprap in canal, 800 square yards	1.50	1.50	.80	2.60	.50	.95	.75	.75	1.00
Placing material in dam:									
110,000 cubic yards rock	1.10	.75	.40	.90	.45	1.00	.75	1.00	.63
101,000 cubic yards earth	.50	.50	.50	1.10	.47	.45	.50	.38	.85
1,200 square yards riprap	1.50	1.50	.80	2.60	.50	.95	.75	.75	2.00
1,000 cubic yards concrete core wall	8.00	9.00	10.00	7.15	8.70	7.00	6.00	11.00	10.00
500 cubic yards excavation in foundation	5.00	5.00	3.00	1.95	3.00	5.00	5.00	3.25	2.00
Spillways:									
3,000 cubic yards concrete	6.00	9.00	8.50	5.20	5.20	6.40	6.00	6.75	8.75
8,000 cubic yards rock in embankments	1.00	1.50	1.00	.90	1.75	1.50	1.00	1.25	1.20
7,200 cubic yards earth and gravel in embankments	.50	.75	.30	1.10	.50	.45	.50	.38	.35
6,500 cubic yards concrete in canal	6.00	9.00	8.50	6.50	5.70	6.40	6.00	6.75	9.75
3,000 pounds steel in same	.08	.06	.08	.10	.07½	.07	.07	.09	.10
57,500 pounds gates and guides for power and irrigation canals	.08	.11	.10½	.16	.12	.14	.09	.09	.128
14 pedestals and screw stems (Coffin ball bearing)	200.00	280.00	244.48	330.00	275.00	275.00	275.00	659.43	290.00
56 flash boards, 8 by 12 inches, bound with ½ by 3 inch strap iron	2.00	3.00	2.00	1.95	5.00	2.50	4.00	1.00	2.25
4,500 pounds steel, 7-inch I-beams for pedestal supports with anchors	.07	.06	.08	.06	.07½	.07	.07	.09	.09
720 cubic yards concrete dam in diversion channel	8.00	9.00	10.00	7.15	12.00	6.00	6.00	6.75	10.00
5 gates and guides for diversion channel (96 by 144 inch Coffin rectangular gates with rising screws and ball-bearing standards complete)	3,000.00	3,275.00	2,990.00	3,684.00	3,550.00	3,500.00	3,500.00	3,334.00	3,800.00
Total	519,627.00	467.538.00	453,387.00	608,510.00	469,094.00	584,785.00	453,659.00	479,082.00	489,311.00

It is interesting to note that the second and tenth lowest bids for the dam, spillway, etc., differ by only about 11 per cent. While there is a considerable difference in bids submitted covering several items of the work, the totals indicate very conservative and careful estimates on the part of the bidders.

The contractors, the Bates-Rogers Construction Company, are now shipping their equipment and in other ways preparing for the active work of construction under their contract, which provides that the work shall be completed within fifteen months from the date of the same, or by November 22, 1905.

CEMENT.

On August 25, 1904, bids were opened at Boise, Idaho, for furnishing 14,000 barrels of Portland cement, to be used in connection with this construction, the lowest bidder being the Utah Portland Cement Company, of Salt Lake City, with which a contract was entered into on September 20, 1904.

The following is an abstract of the proposals:

Bids for furnishing 14,000 barrels of Portland cement, Minidoka project, Idaho.

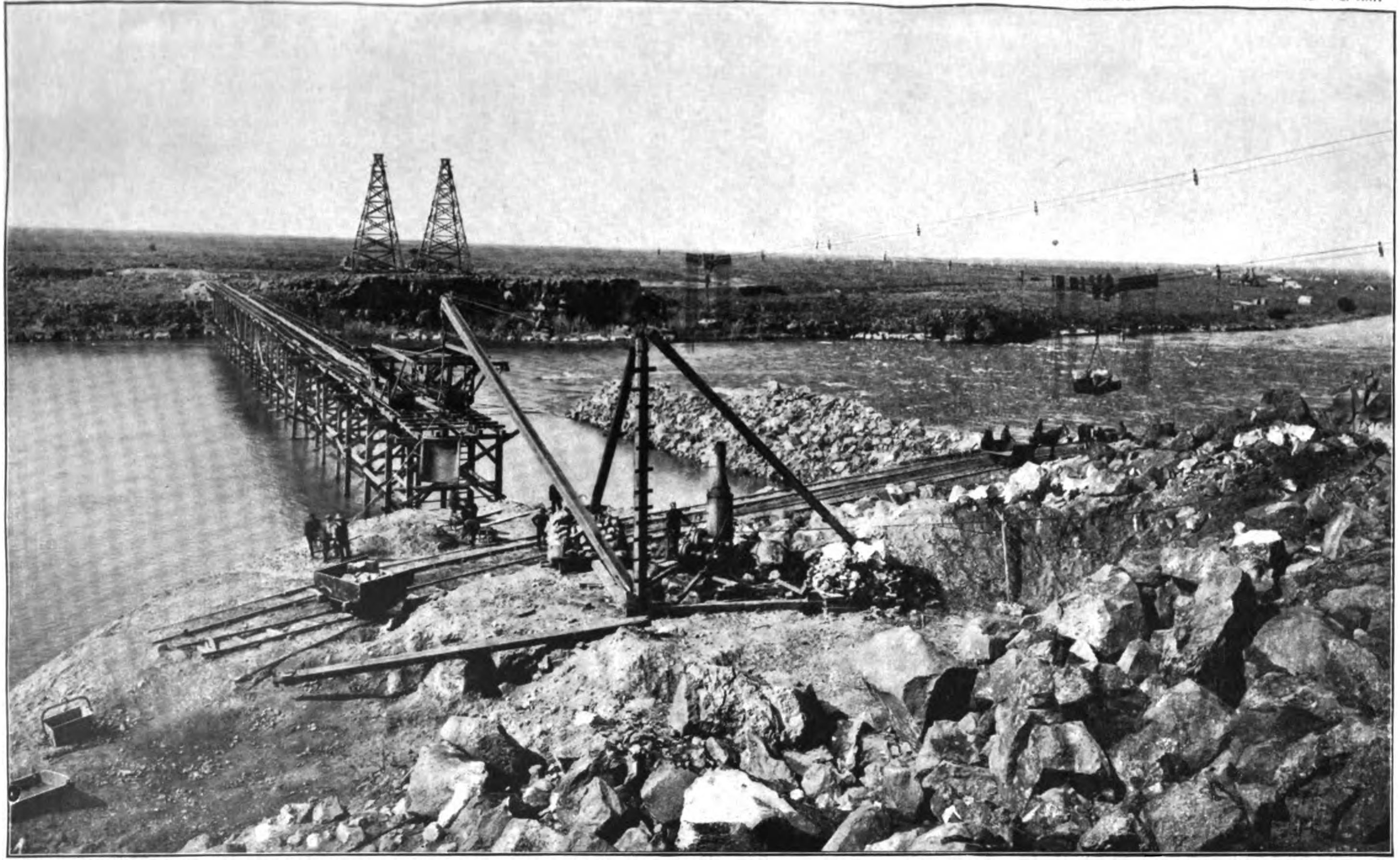
The Utah Portland Cement Company (Limited), Salt Lake City, Utah	$41,300
The Portland Cement Company, Denver, Colo	45,640
The Kansas Portland Cement Company, Iola, Kans	47,180
The Atlas Portland Cement Company, New York, N. Y	51,590

MAIN NORTH-SIDE CANAL AND POWER STATION.

During the latter part of February, 1904, field operations were resumed, surveys being made of several alternative lines for the location of the site for the power house and the main canal on the north side of the river. The site finally selected for the power house is about 2,200 feet from the head-gates, and about 900 feet from the river. As a large portion of the material to be moved in the first mile of the main north-side canal is rock, a great many soundings were made and test pits dug before the location was finally adjusted. Similar investigations were made in the location of the site for the power house, test pits being sunk to the grade of the tailrace, a depth of about 50 feet. The details of these investigations were worked out with the assistance of H. A. Storrs, electrical engineer.

FARM UNITS.

Before notice for bids was published plats were prepared showing farm-unit classifications of all the lands to be irrigated under the project. Reservation was also made of three tracts for town-site purposes. These tracts are situated on the line of the proposed Minidoka and Southwestern Railroad, a branch of the Oregon Short



GENERAL VIEW OF MINIDOKA DAM SITE, MINIDOKA PROJECT, IDAHO, SHOWING TEMPORARY TRESTLE NEAR COMPLETION.

Line Railway which leaves the main line at Minidoka, passing through the Minidoka tract in a southwesterly direction, crossing Snake River about half a mile below the mouth of Goose Creek, and continuing westward through the Twin Falls tract. These town-site reservations were located at points suitable for stations on this line, the most southerly one being on the north side of and at the crossing of Snake River. It was recommended that homestead entries be limited to 40 acres within a radius of 1½ miles from the center of each town site, and 80 acres on all other lands under this project.

SURVEYS AND PLANS.

A plane-table survey was begun in April of the lands on the north side of the river on a scale of 1,000 feet to the inch, with contour intervals of 1 and 2 feet. This survey, which covered an area of about 65,000 acres, was completed during the latter part of August. The work of locating the branch canals and distributing system on these lands is now in progress, and will be completed by the close of the present field season.

A final location has been made of the main canal on the south side of Snake River. This canal will be about 13 miles in length, and will irrigate about 8,000 acres by gravity and conduct water to the pumping stations for elevation to the higher lands on that side of the river; it will have a capacity of about 850 second-feet. The capacity of the main canal on the north side of the river will be about 1,000 second-feet.

During the early part of the field season a survey was made of the back-water line above the dam. The dam will raise the water surface about 47 feet at flood level, backing the water up the river a distance of nearly 35 miles. A careful investigation has been made of the damages which will be done to property along this portion of the river and negotiations for settlement have been entered into. These damages will not be great, and it is thought they can easily be adjusted.

Drawings have been prepared under the direction of A. J. Wiley, consulting engineer, showing the details of construction, and amendments have been made to the original plans wherever deemed necessary. A preliminary study of power development has been begun by H. A. Storrs. Several different plans have been prepared for the purpose.

It is hoped that surveys are far enough advanced to permit the letting of contracts during the coming winter for the construction of the entire gravity system of canals under this project. In the letting of contracts for this work it will be recommended that provision be made so that a large portion of the work can be done by the settlers themselves.

PAYETTE-BOISE PROJECT.

The investigations made during the field season of 1903 of the Payette-Boise project pointed to the feasibility of reclaiming practically all of the irrigable lands of the Payette and Boise valleys. The plans proposed contemplate the construction of two main canals in the Boise Valley, one on the south, the other on the north side of the river. The construction of a dam on Payette River and a canal on the south side of the Payette Valley will divert water for irrigating the lands above the existing canals and in the lower portion of Boise Valley, about 55,000 acres in all. It will also be feasible to irrigate practically all of the reclaimable land on the north side of Payette River from the same point of diversion.[a] Pl. XXV is a general map of the Payette-Boise project.

As the larger portion of the land under this project is held in private ownership, it was decided that no further steps should be taken by the Reclamation Service until after it was ascertained whether the landowners generally desired the Government to take up the work and would perfect the necessary organization.

During the month of December, 1903, steps were taken by a few leaders in the Payette and Boise valleys with a view of arousing a general public interest in the project. Meetings were held at many places and the possibilities and benefits of the project discussed. A great deal of interest was taken in the matter by the landowners. A representative organization committee was the result of this movement, which took charge of the work and the interests of the landowners and irrigators, circulating petitions and doing all things necessary to place the claims of the people before the Department of the Interior.

On March 4, 1904, a communication was addressed to the Secretary of the Interior, transmitting a copy of the proceedings of the committee on organization. These proceedings contained minutes of mass meetings held at various places in these valleys, resolutions of boards of trade, town councils, and irrigation associations, and petitions signed by landowners representing more than 90,000 acres of land, and a resolution by the State board of land commissioners representing the interests of the State in about 60,000 acres of land, all asking that the Government continue the investigations with a view of beginning the work of construction upon the perfecting of such an organization of landowners as would be approved by the Secretary, and pledging their cooperation and support in carrying out the project. This communication, which was afterwards printed as Senate Document No. 247, was referred to the Director of the United States Geological Survey, who recommended to the Secretary that surveys and examinations be continued, leading up to a definite statement of probable cost; that the people interested be encouraged to effect the organization and make suitable arrangements for acquiring vested rights or quieting conflicting claims; and that construction be undertaken in the future, if the physical conditions are found to be satisfactory and the people interested are able to bring about a solution of the many problems involved. These recommendations were approved by the Secretary.

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[a] Second Annual Report of the Reclamation Service, pp. 297 to 325.

WATER USERS' ASSOCIATION.

The favorable action taken by the Geological Survey on the report of the organization committee encouraged the landowners to take the next step necessary, viz, the organization of a water users' association. In organizing this association full advantage was taken of the experience of the irrigators in the Salt River Valley, Arizona. Articles of incorporation were prepared and, after having been submitted to the legal advisers of the Reclamation Service, were formally executed and filed, and a permanent organization, known as the Payette-Boise Water Users' Association, was thus formed. This association was formally organized on August 10, 1904; a board of directors of 11 members was elected, of which Mr. J. H. Lowell, of Caldwell, Idaho, is president and Mr. A. A. Richards, of Emmett, Idaho, is secretary; by-laws were adopted, and a form of stock-subscription agreement was prepared. These by-laws and agreements were submitted to the Reclamation Service at Washington for criticism and approval, and were later amended in accordance with suggestions made by F. H. Newall, chief engineer.

Meetings are now being held at different points throughout the Boise and Payette valleys for the purpose of explaining to the irrigators details of the organization and of the work proposed and soliciting stock subscriptions. It is expected that formal contracts covering practically all of the lands held in private ownership will be entered into with the association before the end of December. It is also hoped that arrangements can be entered into by the various irrigation communities looking to the consolidation of irrigation systems with a view of placing themselves in harmony with the more comprehensive plans of the Government.

Following are the articles of incorporation of the association:

ARTICLES OF INCORPORATION OF THE PAYETTE-BOISE WATER USERS' ASSOCIATION (LIMITED).

Know all men by these presents, that we, whose names are subscribed hereto, do, under and pursuant to the provisions of the general corporation laws of the State of Idaho and all amendments thereto, associate ourselves together for the purpose of forming a corporation, and to that end execute the following, which shall constitute the articles of incorporation of the Payette-Boise Water Users' Association (Limited):

First. The name of this corporation is and shall be Payette-Boise Water Users' Association (Limited).

Second. The purposes for which this corporation is organized are:

To acquire, furnish, provide for, and distribute to the lands of the shareholders of this corporation an adequate supply of water for the irrigation thereof; to divert, store, impound, pump, develop, carry, deliver, and distribute water for irrigation and all other beneficial uses, deriving the same from all available sources of supply; to construct, purchase, lease, condemn, or acquire in any manner whatsoever, and to own, use, sell, transfer, convey, control, maintain, and operate any irrigation works, structures, telephone systems, electric or other power plants and transmission lines, and property, both real and personal, of every kind whatsoever necessary or appropriate for the accomplishment of any of the purposes of this organization; to generate, create, transmit, use, and sell power and electrical energy; to act as trustee, agent, or attorney for the sale, disposal, and transfer of lands tributary to any irrigation system operated by this corporation, in order to facilitate the disposal of such lands, or any part thereof, to persons qualified to perfect right to the use of water under the laws of the United States applicable thereto and the rules and regulations established thereunder; to do and perform all such other acts and things as may be requisite and necessary or appear suitable or convenient for the accomplishment of any of the purposes or the attainment of any one or more of the objects herein enumerated or incidental thereto, or which shall at any time appear conducive or expedient for the protection or benefit of the association or its shareholders, and to that end enter into any contract or other arrangement with the proper representative of the United States or any other person for the accomplishment of any of the aforesaid purposes, by means of the construction, acquisition, or control of appropriate works or structures, or in any manner whatsoever, and to enter into any agreement with the proper representative of the United States with reference to the collection and payment of any and all charges made under the Federal statutes for the works providing water for the lands of its shareholders.

Third. That the place where the principal business of this corporation shall be transacted is the town of Caldwell, in Canyon County, State of Idaho.

Fourth. The corporate existence of this corporation shall be limited to the term of fifty years from the date of its incorporation.

Fifth. The corporate powers of this corporation shall be vested in a board of eleven directors, and the names and residences of those who are appointed as directors for the first year of the life of this corporation, or until their successors are elected and qualified, are as follows: J. H. Lowell, Caldwell, Idaho; D. R. Hubbard, Boise, Idaho; H. A. Partridge, Nampa, Idaho; A. R. Stalker, Meridian, Idaho; E. M. Kirkpatrick, Parma, Idaho; A. A. Richards, Emmett, Idaho; A. J. Howd, Emmett, Idaho; A. J. Mitchell, Parma, Idaho; Frank Steunenberg, Caldwell, Idaho; C. E. Paine, Roswell, Idaho; Jesse Walling, Nampa, Idaho.

Sixth. The amount of the authorized capital stock of this corporation shall be five million seven hundred thousand ($5,700,000) dollars, divided into three hundred and eighty thousand (380,000) shares of the par value of fifteen ($15) dollars each.

Seventh. The amount of the capital stock of this corporation that has been actually subscribed, and the number of shares subscribed by each subscriber, and the par value thereof, are as follows:

Name of subscriber.	Number of shares.	Par value.
J. H. Lowell	1	$15
D. R. Hubbard	1	15
H. A. Partridge	1	15
A. R. Stalker	1	15
E. M. Kirkpatrick	1	15
A. A. Richards	1	15
A. J. Howd	1	15
A. J. Mitchell	1	15
Frank Stunenberg	1	15
C. E. Paine	1	15
Jesse Walling	1	15

In witness whereof we have hereunto set our hands and seals this 9th day of September, 1904.

[SEAL.] D. R. HUBBARD.
[SEAL.] H. A. PARTRIDGE.
[SEAL.] A. A. RICHARDS.
[SEAL.] A. J. MITCHELL.
[SEAL.] A. J. HOWD.

STATE OF IDAHO, *County of Ada, ss:*

On this 9th day of September, 1904, before me, I. W. Hart, a notary public in and for said Ada County, State of Idaho, personally appeared D. R. Hubbard, H. A. Partridge, A. A. Richards, A. J. Mitchell, and A. J. Howd, known to me to be the persons whose names are subscribed to the within instrument, and acknowledged to me that they executed the same.

In witness whereof I have hereunto set my hand and affixed my notarial seal the day and year in this certificate first above written.

[SEAL.] I. W. HART, *Notary Public.*

STATE OF IDAHO, *County of Ada, ss:*

H. A. Partridge, being first duly sworn according to law, upon his oath deposes and says that he is one of the individual persons who subscribed to the foregoing articles of incorporation, and that he then was and now is a bona fide resident of the State of Idaho.

H. A. PARTRIDGE.

Subscribed and sworn to before me this 9th day of September, 1904.

I. W. HART, *Notary Public.*

BY-LAWS OF THE PAYETTE-BOISE WATER USERS' ASSOCIATION (LIMITED).

ARTICLE I.—*Provisions relating to water rights and to the matters subject to the operations of the reclamation act.*

SECTION 1. *Territory.*—The territory within which the lands to be irrigated are situated, to be known as the "Payette-Boise irrigation district," includes all lands within the boundaries described as follows:

Such portions of Ada, Canyon, and Owyhee counties, in Idaho, lying along the Payette, Boise, and Snake rivers, as may be included in the Government reclamation project as surveyed and outlined and finally approved by the Secretary of the Interior, and known as the "Payette-Boise project."

SEC. 2. *Membership.*—Only those who are owners of lands, or occupants of public lands having initiated a right to acquire the same, within the area described in section 1, or within such extensions thereof as may hereafter be duly made, shall be qualified to own the shares of this association. Not more than one share shall be allotted for each acre of land or fraction thereof.

SEC. 3. *Stock subscription and contract.*—Each of the shareholders in this corporation shall subscribe to a form of stock subscription and contract for the stock subscribed by him, and hereafter no subscriptions for stock shall be taken or stock issued except the applicant has subscribed to said form of stock subscription and contract, which shall be signed, executed, and acknowledged by the applicant in the same manner as required by law for the execution and acknowledgment of deeds for the conveyance of real property.

Said form of stock subscription and contract shall be as follows:

STOCK SUBSCRIPTION AND CONTRACT.

Know all men by these presents, that I, ——— ———, do hereby subscribe for and agree to take —— shares of the capital stock of the Payette-Boise Water Users' Association (Limited), a corporation duly organized under the laws of the State of Idaho, and in conformity with the by-laws of said association and in consideration of the benefits to be received therefrom, I hereby covenant and agree as follows:

The said shares of stock and all rights and interests represented thereby or existing or accruing by reason thereof, or incident thereto, are to be inseparably appurtenant to the following-described real estate, that is to say: ——— ——— ——— ———.

The undersigned hereby agrees that the right to any water heretofore appropriated by him or by his predecessors in interest for the irrigation of the lands above described or customarily used thereon shall become appurtenant to such lands and be and remain incident to the ownership of the above shares appurtenant to such lands. There shall be further incident to the ownership of such shares the right to have such water delivered to the owner thereof by the association for the irrigation of said lands, as the association shall from time to time acquire or control means for that purpose: *Provided*, That the whole amount of water actually delivered to such lands from all sources shall not exceed the amount necessary for the proper cultivation thereof.

It is agreed and understood that the records of the association, as well as the certificate or other evidence of ownership of the shares of stock in the association when issued, shall contain a description of the land to be irrigated, as above described, and to which the aforesaid rights and shares shall be perpetually appurtenant, and hereafter all rights, whatever their source or whatever their manner of acquisition, to the use of water for the irrigation of said lands shall forever be inseparably appurtenant thereto, together with the said shares of stock, and all rights and interests represented thereby or existing or accruing by reason thereof, unless such rights shall become forfeited under the provision of this contract or of by-laws of this association, or by operation of law, or by the voluntary abandonment thereof by deed, grant, or other instrument, or by nonuser for the term prescribed by law; but no such abandonment shall be for the benefit of any person designated by the undersigned or his successor, directly or indirectly, or to his use, nor confer any right whatsoever upon the holder of any grant, release, waiver, or declaration of abandonment of any kind: *Provided, however*, That if for any reason it should at any time become impracticable to beneficially use water for the irrigation of the land to which the right to the use of the water is appurtenant, the said right may be severed from said land and simultaneously transferred and attached to other lands to which shares of stock in this association are or shall thereby be made appurtenant, if a request for leave to transfer, showing the necessity therefor, shall have first been allowed by a two-thirds vote of the board of directors at a regular meeting and approved by the Secretary of the Interior.

Every transfer of the title to said lands to which the said rights and shares are appurtenant, whether by grant or by operation of law (except where the land may be subjected by grant, or involuntarily under any law, to an easement, the exercise of which does not interfere with the cultivation of the soil by the servient owner), shall operate, whether it be so expressed therein or not, as a transfer to the grantee or successor in title of all rights to the use of water for the irrigation of said lands, also all rights arising from, or incident to, the ownership of such shares, as well as the shares themselves; and upon presentation to this association of proof of any such transfer of land, the proper officers shall transfer such shares of stock upon its books to the successor in title to said lands.

Any transfer or attempted transfer of any of the above shares of this association, made or suffered by the owner thereof, unless simultaneously a transfer of the land to which it is appurtenant, is made or suffered to or in favor of the same party, shall be of no force or effect for any purpose, and shall confer no rights of any kind whatsoever on the person or persons to whom such transfer may have been attempted to be made.

As a condition of continued ownership of said shares of stock and participation in any of the benefits thereof, the undersigned, or his transferee, agrees to make prompt application for a water right to the proper authorities of the United States for the land represented by his shares, and duly proceed to the perfection thereof, in full compliance with the law applicable thereto, and the rules and regulations estabilshed in pursuance thereof, as soon as official announcement shall be made that water for such lands is available from the works constructed, owned, or controlled by the United States.

Upon the failure of the undersigned or his successor to make prompt application for such water right for the said land or to comply promptly and in good faith with the law and the rules and regulations applicable thereto, he shall forfeit to the association the said shares of stock and all rights incident thereto or that could by any means be claimed thereunder; and the undersigned, his heirs and assigns, shall thereafter have no right whatsoever as a member or shareholder of this association, as to such shares.

No payments for the shares of capital stock of this association shall be required, except in the manner following: The undersigned shall, as prescribed in this contract, make application to the proper representative of the United States for a water right, at the rate of not to exceed one share for each acre. Upon proper proof to the association that such application has been accepted and that he has complied with all the requirements in relation thereto, such subscriber shall be deemed to have paid on his stock subscription the amount then paid to or for the use of the United States for such rights; and when all the payments required for such right shall have been made, and when proper evidence of the perfection of such water right has been issued, his stock shall be deemed and held to have been fully paid up; and until fully paid the payments due thereon shall be a lien upon such lands and shares and the said lien enforced by foreclosure and sale of said stock and lands, or so much thereof as may be necessary, in the manner provided by law for the foreclosure of mortgages; and the purchaser at such sale shall be entitled to the benefit of all payments on the water right appurtenant to the land purchased, and shall take said lands subject to the obligations and conditions herein provided.

Assessments shall become, from time to time, as they are made and levied, a lien on the said lands of the undersigned and his transferee against which they are levied, and upon the said shares of stock and all rights and interests represented by such shares; and until they are paid or otherwise discharged shall be and remain a lien thereon. The manner of enforcing said lien shall be by foreclosure and sale of the stock and lands as herein provided for payments on capital stock.

In witness whereof we have hereunto set our hands and seals this —— day of ———, 190—.

[SEAL.] ——— ———

[SEAL.] ——— ———

STATE OF IDAHO, *County of* ———, *ss:*

On this —— day of ———, in the year nineteen hundred and ———, before me, ——— ———, a notary public in and for said county, personally appeared ——— ———, known to me to be the person whose name is subscribed to the within instrument, and acknowledged to me that he executed the same; and on this —— day of ———, 190—, before me, the officer above described, personally appeared ——— ———, known to me to be the person whose name is subscribed to the within instrument, described as a married woman; and upon an examination without the hearing of her husband I made her acquainted with the contents of the instrument, and thereupon she acknowledged to me that she executed the same, and that she does not wish to retract such execution.

In witness whereof I have hereunto set my hand and affixed my official seal the day and year in this certificate first above written.

[SEAL.] ——— ———, *Notary Public.*

The above subscription and contract was accepted and approved by the Payette-Boise Water Users' Association (Limited) at a meeting of the board of directors held on the —— day of ———, 190—.

PAYETTE-BOISE WATER USERS' ASSOCIATION (LIMITED),
By ——— ———, *President.*

Attest:
[SEAL.] ——— ———, *Secretary.*

And such stock subscription and contract shall become binding only upon the association when approved and executed by the association.

SEC. 4. *Forfeiture of stock.*—Any shares of stock which may be forfeited under the provisions of the stock subscription and contract, as set forth in section 3, Article I, of these by-laws, shall not again, under any circumstances, be renewed, revised, or reissued. Other stock in lieu thereof up to the limit of the total number of shares authorized by these articles may be subscribed for and issued, subject to all the conditions of these articles and to the approval of the Secretary of the Interior.

SEC. 5. *Right to have water delivered.*—The ownership of each share of stock of this association shall carry, as incident thereto, a right to have water delivered to the owner thereof by the association for the irrigation of the lands to which such share is appurtenant.

SEC. 6. *Right to proportionate part of water.*—The amount of water to be delivered to such owner shall be that proportionate part of all the water available for distribution by the association during any irrigation season as the number of shares owned by him shall bear to the whole number of valid and subsisting shares then outstanding, such water to be delivered to and upon said lands at such times during such season as he may direct: *Provided*, That in case of an insufficient supply of water for all lands owned by the stockholders, distribution of water as in this section provided shall be subject to priority of rights as provided in Article VIII of these by-laws.

SEC. 7. *Water rights made appurtenant to land.*—The records of the association and each and every certificate or other evidence of ownership of the shares of stock in the association, when issued, shall contain a description of the lands to be irrigated, and to which the aforesaid rights and shares shall be perpetually appurtenant; and thereafter all rights, whatever their source or whatever their manner of acquisition, to the use of water for the irrigation of said lands, shall forever be inseparably appurtenant thereto, together with the said shares of stock, and all rights and interests represented thereby or existing or accruing by reason thereof, unless such rights shall become forfeited under the provisions of these by-laws or by operation of law, or by the voluntary abandonment thereof by deed, grant, or other instrument, or by nonuser for the term prescribed by law; but no such abandonment shall be for the benefit of any person designated by such shareholder, directly or indirectly, or to his use, nor confer any right whatsoever upon the holder of any grant, release, waiver, or declaration of abandonment of any kind: *Provided, however,* That if for any reason it should at any time become impracticable to beneficially use water for the irrigation of the land to which the right to the use of the water is appurtenant, the said right may be severed from said land and simultaneously transferred and attached to other lands to which shares of stock in this association are or shall be made appurtenant, if a request for leave to transfer, showing the necessity therefor, shall have first been allowed by a two-thirds vote of the board of directors at a regular meeting and approved by the Secretary of the Interior.

SEC. 8. *Transfer of title.*—Every transfer of the title to any lands to which the said rights and shares are appurtenant, whether by grant or by operation of law (except where the lands may be subjected by grant, or involuntarily under any law, to an easement, the exercise of which does not interfere with the cultivation of the soil by the servient owner), shall operate, whether it be so expressed therein or not, as a transfer to the grantee or successor in title of all rights to the use of water for the irrigation of said lands, also all rights arising from, or incident to, the ownership of such shares, as well as the shares themselves; and upon presentation to this association of proof of any such transfer of land the proper officer shall transfer such shares of stock upon its books to the successor in title to said lands.

SEC. 9. *Transfer of shares, when void.*—Any transfer or attempted transfer of any of the shares of this association, made or suffered by the owners thereof, unless simultaneously a transfer of the land to which it is appurtenant is made or suffered to or in favor of the same party, shall be of no force or effect for any purpose, and shall confer no rights of any kind whatsoever on the person or persons to whom such transfer may have been attempted to be made.

SEC. 10. *Shares must not exceed available water supply.*—If it should be determined by the United States that the amount of water available from the entire irrigation system as owned or controlled by it and by the association shall be insufficient to properly irrigate 1 acre of land for each share of the capital stock, then the number of shares shall be so reduced as not to exceed the number of acres determined by the United States as irrigable from the entire available supply of water.

SEC. 11. *Allotment of shares.*—Upon the determination by the United States of the number of acres irrigable, no shares in excess thereof shall be issued. If, when such determination is made, the number of shares subscribed shall be in excess of the number of acres so determined, an allotment of shares shall be made to the subscribers equal to the number of acres irrigable, giving preference to cultivated land. The surplus of shares so subscribed shall thereupon be canceled and shall not be reissued. By-laws shall be adopted to govern such allotment.

SEC. 12. *Amendment of articles of incorporation.*—If the number of acres of irrigable land or the cost of the works, or both, as determined by the United States, shall exceed the number of shares or the capital stock authorized herein, appropriate amendment of the articles of incorporation as to the number of shares, the par value thereof, and the capital stock shall be made in compliance with the laws applicable thereto.

SEC. 13. *Amendments must be approved by the Secretary.*—No provision of any by-law embraced in Article I of these by-laws can be amended or modified, except upon the approval of the Secretary of the Interior or his representative.

ART. II.—*Meetings of stockholders.*

SECTION 1. The annual meeting of the stockholders of the association shall be held at the office of the association on the second Monday of January, at the hour of 3 o'clock in the afternoon.

SEC. 2. Notice of such annual meeting shall be mailed by the secretary to each member of this association, to his last known place of residence, not less than fifteen days before the date of holding such meeting.

Special meetings.

SECTION 1. Special meetings of the stockholders of this association may be called at any time upon order of the board of directors, entered upon the minutes of such board, showing the purpose or purposes for which such meeting is called.

SEC. 2. Notice of such meeting, embracing the order of the board calling such meeting, must be mailed to each stockholder of this association not less than twenty days before the date of holding such meeting, addressed to his last known residence.

ART. III.—*Board of directors.*

SECTION 1. *Number and length of term.*—The exercise of the corporate powers of this association and the management of its affairs shall be vested in eleven directors, elected to serve one year.

SEC. 2. *Qualifications.*—Each director shall, at the time of his election, be the owner of lands situated within the irrigation district to which shares of stock of this association are appurtenant, and shall also be a resident of the district.

SEC. 3. *Vacancies.*—If a person elected as a director shall, at any time during his term of office, cease to have any of the qualifications prescribed, such office shall thereupon become vacant. In the event of a vacancy from that cause, or by reason of death or resignation, the vacancy shall be filled by the board of directors.

SEC. 4. *Elections.*—The annual election of directors shall be held on the second Monday in January in each year, in such manner as the by-laws may provide.

SEC. 5. *Meetings.*—Regular meetings of the board of directors shall be held on the second Tuesday of each month. Special meetings of the board of directors may be called by the president or by any three of the members of the board. Such call shall be in writing and signed by either the president or any three directors, and shall state the time of such proposed meeting and the nature of the business to be transacted thereat. Such written call shall be filed with the secretary, who shall thereupon immediately, and at least five days before the time fixed for such meeting, mail, post paid, to the president and each member of the board a copy of such call. If the secretary fail or refuse to mail copies thereof, as above provided, then either the president, if he issue the call, or any one of the members who issued the same may make and mail copies of the call, with like effect as if done by the secretary. All meetings of the board of directors shall be held at the office of the association.

SEC. 6. *Powers of the board—(a) Lawsuits and contracts.*—The board of directors shall have the power to prosecute, defend, and compromise all lawsuits and to make all contracts, in the name of the association, necessary and proper for the conduct of the affairs and the carrying on of the business of the association, subject to all limitations and regulations prescribed by the articles of incorporation or these by-laws.

(*b*) *Assessments.*—The board shall have the power to estimate, make, and levy all assessments against the shareholders of this association to the extent and in the manner authorized by the articles of incorporation and these by-laws.

(*c*) *Distribution of water.*—The board shall have power to make, publish, and enforce rules and regulations concerning the distribution, use, and application of the water under the control of the association, subject at all times to and not inconsistent with the articles of incorporation or with the by-laws, or with the Federal statutes applicable thereto and the rules and regulations established thereunder.

(*d*) *May create offices.*—The board of directors may create such other offices as may be necessary for the carrying on of the business and affairs of this association. and prescribe the manner of appointment, powers, duties, terms of office, eligibility, and compensation thereof by by-laws.

(*e*) *May remove from office.*—The board of directors may remove from office any officer, appointee, or employee.

SEC. 7. *Records of the board.*—The board shall keep or cause to be kept a record of its transactions, which shall at all times remain in the office of the association, and shall, during office hours, be open to the inspection of the shareholders, or their properly authorized agents.

SEC. 8. *Complaints to the board.*—The board shall hear and determine complaints of shareholders of nonservice or of improper service or distribution of water, or of improper performance of duty by any employee of the association relative to the distribution of water.

SEC. 9. *Compensation.*—The members of the board of directors shall receive such compensation as may be prescribed by the shareholders at annual meeting.

ART. IV.

SECTION 1. *Adoption, repeal, and amendment of by-laws.*—The board of directors shall have power to enact, adopt, and provide for the enforcement of by-laws, not inconsistent with the articles of incorporaton, for the government of the members of the association, for the management of its business, and the conduct of its affairs; and to repeal, modify, and amend the same from time to time. But the board of directors shall not have the power to adopt or to enforce any by-laws that in any wise conflict with any Federal statutes or the rules and regulations established thereunder for the administration of water from any reservoir or other works acquired, constructed, or controlled by the United States and which may be used for supplying water to the lands of the shareholders of this association. But all by-laws or amendments thereof enacted by the board of directors shall be void after the next annual meeting of the shareholders unless approved by such shareholders at such meeting.

SEC. 2. No by-laws shall be passed or enforced which shall interfere with or affect any present existing vested right of any member of this association to the use of water for irrigation.

SEC. 3. *By-laws to be of general application.*—All by-laws shall be of general application so far as general laws can be made to apply.

ART. V.—*Revenues.*

SECTION 1. Revenues necessary for the accomplishment of the purposes of this association shall be raised by an assessment thereof from time to time as required, upon and against the shareholders.

SEC. 2. The board of directors shall have power to make, amend, and enforce necessary by-laws for the making, levying, collecting, and enforcing of such assessments.

ART. VI.—*Elections.*

SECTION 1. *Qualifications of electors.*—At all elections the electors shall possess the following qualifications: Shall be, at the time of the election, the owner of at least 1 share of the capital stock of this association, and shall have been the owner thereof, as shown by the books of the association, for at least twenty days before such election.

SEC. 2. *Votes to which each shareholder is entitled.*—At all elections each shareholder shall be entitled to one vote for each share of stock owned by him, not, however, to exceed, in the aggregate, 160 votes.

SEC. 3. *Manner of voting.*—The votes shall be by written or printed ballot, and be voted only by the electors at the polls in person.

SEC. 4. *Method of holding elections.*—The board of directors may make reasonable by-laws for the registration of voters and the method of holding elections.

SEC. 5. *Highest number of votes elects.*—The party receiving the highest number of votes for any office shall be deemed elected to such office.

ART. VII.—*Officers.*

SECTION 1. *Duties and compensation.*—The president, vice-president, treasurer, and secretary shall perform such duties as are prescribed by these by-laws, wherein such by-laws shall not be inconsistent with law or with the articles of incorporation, and shall receive such compensation as may be fixed by the by-laws, which compensation shall neither be increased nor diminished during their respective terms of office.

SEC. 2. *President.*—The president shall be the chief executive officer of the association, and shall have general supervision over all other officers of the association in the performance of their duties as such, and of the conduct of the business and affairs of the association. He shall preside at all meetings of the board of directors, and shall perform such other duties as may be devolved upon him by the by-laws.

SEC. 3. *Vice-president.*—In case of the absence, illness, or inability of the president to act, from any cause, or in case of a vacancy in that office, the vice-president shall act in the place and stead of the president.

SEC. 4. *Treasurer.*—The treasurer shall receive and be the custodian of all moneys and other funds of the association. No moneys shall be paid out by the treasurer unless upon warrants drawn on him by the president and secretary. No warrant shall be drawn on the treasurer by the president and secretary except upon the order of the board of directors, recorded in the minutes of the board, and in a warrant record to be kept by the secretary.

SEC. 5. *Treasurer to make reports.*—The treasurer shall keep a full, complete, and accurate account of all moneys of the association received and disbursed by him, in books belonging to the association, and shall present a report and account thereof at every regular meeting of the board, and shall, at the expiration of each quarter, prepare and publish, in such manner as the by-laws may prescribe, a quarterly statement to shareholders showing all such receipts and disbursements during the last preceding quarter; and the treasurer shall perform such other duties as may be devolved upon him by the by-laws or by the board of directors.

SEC. 6. *Secretary.*—The secretary shall act as the clerk of the board of directors and keep a record of all their proceedings. He shall immediately upon their adoption record in a book of by-laws, to be kept by him in his office, all by-laws adopted, and shall keep such book open to the inspection of any member of the association or his properly authorized agent at all times during business hours. And the secretary shall perform such other duties as may be devolved upon him by the by-laws or by the board of directors.

SEC. 7. *Bonds.*—The treasurer and secretary shall give such bond as may be prescribed by the by-laws: *Provided,* That neither the president, vice-president, or any member of the board of directors or the secretary shall be accepted as a surety on the bond of the treasurer.

ART. VIII.—*Water rights.*

Nothing in the articles of incorporation or in the fact of becoming a member of this association shall be construed as affecting, or intended to affect, or to in any way interfere with the vested rights of any person to the prior use or delivery of any waters.

ART. IX.—*Seal to be affixed.*

All certificates or other evidence of the ownership of shares of stock in the association shall have the seal of the association affixed.

ART. X.—*Contracts, how executed.*

All the contracts and instruments in writing executed for or on behalf of the association shall be executed in the name of the association by the president and secretary, and shall have the seal of the association affixed.

ART. XI.

Amendments.—These by-laws shall not be amended so as to in any wise conflict with any Federal statutes, or the rules and regulations established thereunder, for the administration of water from any reservoir or other works acquired, constructed, or controlled by the United States and which may be used for supplying water to the lands of the shareholders of this association.

Seal.—The seal of this association shall be a figure of two concentric circles, the outer being 1¾ inches and the inner 1¼ inches in diameter. In the space between the two shall be the words "Payette-Boise Water Users' Association, Ltd., Idaho," and bearing within the center space an unrolled scroll with the words and figures thereon, "Incorporated, 1904."

SURVEYS IN THE PAYETTE AND BOISE VALLEYS.

Investigations in the Payette and Boise valleys were resumed in April, 1904.

The following are the canal surveys made: The proposed main canal on the south side of the Payette Valley; the proposed main canal, the Farmers' Union ditch, and the Farmers' Cooperative, or Sebree, canal, on the north side of the Boise Valley; the proposed main canal, the New York, the Ridenbaugh, and the Riverside canals, on the south side of the Boise Valley. Canal lines were also run on the south side of Snake River near the Idaho-Oregon State line. Line topography has been taken with plane table on all of these lines. Detail surveys were made at the proposed dam site near the mouth of the Boise Canyon and at the heads of the Ridenbaugh, Farmers' Union, Phyllis, Caldwell, Riverside, and Sebree canals. A detail survey was also made of the Black Rock Canyon dam site on Payette River. Borings are now in progress at the site of the proposed diversion dam near the mouth of the Boise Canyon. Test pits have been dug along all the lines mentioned with a view of ascertaining the character of the material to be excavated, and pits sunk to grade on the divide between the Payette and Boise valleys at the point where the south side Payette canal will cross over into Boise Valley.

It was found as these investigations progressed that many of the difficulties which it was at first thought would be quite serious can be easily overcome. For instance, it was thought that it would be necessary to install a pumping plant on the divide between the valleys, but it has been found that it will be entirely feasible to carry the water from Payette to Boise Valley through the divide in an open cut. The tunnel, which will have to be constructed in avoiding the Dewey Railroad, will be much shorter than was at first estimated. It has also been found that a great saving can be effected in the construction of the main canal on the south side of Boise Valley by utilizing about 8 miles of the channel of Indian Creek. Many other features of the work have been found to involve fewer difficulties than were at first supposed to exist.

RESERVOIR SITES.

BOISE RIVER.

Two surveys were made on Boise River in June and July, 1904, which have a direct bearing upon this project. These surveys were supplementary to the reconnaissance surveys made in 1902 by the State engineer in cooperation with the United States Geological Survey. One of them was made on Middle Fork of Boise River at Alexander's ranch, the other on North Fork at Rossi's logging camp. At Alexander's ranch on Middle Fork a survey was made on a shore line 130 feet above the river at the dam site. This will probably be the maximum height, depending upon the bed-rock conditions in the left abutment. It was found that the capacity of the reservoir at this level will be 25,000 acre-feet. The dam will be 500 feet long on top and 75 feet at the base. The original survey was made on the 100-foot level, which required a dam 400 feet long on top and gave a capacity of 14,000 acre-feet. Construction at this place will be very simple, since rock can be handled almost entirely by gravity, while all lighter material can be hydraulicked into place. The basin is a small valley situated in a granite formation, and storage will be very efficient.

At Rossi's logging camp, on the North Fork, it was found that a dam to raise the water 130 feet will be 480 feet long on top and about 110 feet at the base. This dam will back the water up a distance of about 3½ miles and give a storage capacity of over 34,000 acre-feet. The natural conditions seem favorable at this place for a very efficient storage basin, and there is little doubt that the foundation for dam construction is excellent, and that the same plan of construction can be followed as at the Alexander ranch.

The surveys of these sites were made by Fred Stockton, assistant engineer.

During the early part of August, 1904, a reconnaissance on South and Middle forks of Boise River was made by D. W. Ross, district engineer, and A. J. Wiley, consulting engineer. Several basins were examined, some of which appeared quite promising. A large basin exists on the South Fork in the vicinity of Pine, but the conditions at the dam site are not very favorable. The best dam site examined in connection with this basin is situated about 1 mile below the mouth of Lime Creek, near the upper edge of the lava flow in this region. The valley at this point is about 400 feet wide, the bed rock being granite overlain by a deposit of lava which might furnish a suitable abutment on the south side, but consists of loose bowlders on the north. A dam from 125 to 150 feet in height will be required at this place, but it is very doubtful if it will be feasible to construct one under the conditions which exist.

There is another basin about 8 miles above the town of Pine which has a very good dam site, all in granite, where the conditions are favorable for the construction of a dam from 100 to 150 feet in height. Another site was examined on the main river near the end of the wagon road. At this point there is a very good dam site situated just below the mouth of Willow Creek, also in granite. Surveys of the two latter sites are now in progress, and it is hoped that conditions will be found favorable for the storage of a large amount of water.

An excellent dam site was also found on the main Boise River about one-half mile below the mouth of Sheep Creek. The river at this point is about 75 feet wide, the formation being solid granite and the conditions being very favorable for the construction of a high dam. The site seemed so favorable that a survey was at once made by Fred Stockton, but it was found that the storage facilities were not what was at first estimated, as a dam 225 feet high would only provide storage for 55,000 acre-feet. This dam site is below the junction of the North and South forks, and while it would back the water more than 3 miles up both of these branches the basin is so narrow that it is very doubtful if the plan will be at all practicable.

It would seem from investigations which have been made to date that storage on the headwaters of Boise River will be very expensive. The basins which have so far been surveyed are comparatively small and all require the construction of very high dams. While the conditions are favorable for the construction of these dams, the cost will necessarily be very great, owing to their height.

PAYETTE RIVER.

During July, 1904, a reconnaissance was made of the headwaters of Payette River by Fred Stockton, assistant engineer, to determine the feasibility of storing water at several places. All basins of any considerable size on East and Middle forks were looked over, but the North Fork showed far better advantages for storing. There are three sites on this fork that are particularly striking, viz, Long Valley, Big Payette Lake, and Little Payette Lake. As the amount required to be stored will not likely exceed 150,000 acre-feet, Big Payette Lake offers the best facilities for the purpose.

Long Valley is an excellent basin and could be developed to have an enormous capacity. The dam site is good and the basin very flat, but the land which would be flooded is all patented and much of it is improved. The right of way therefore would be very expensive, and this plan would perhaps be impracticable, unless it is desired to develop a very large capacity. Little Payette Lake is a good site, but has an area of only a little over 500 acres. It has a good dam site near its outlet, but the expense of developing this site would be so much greater than the work on Big Payette Lake that it is not worth considering.

At Big Payette Lake conditions are very favorable for storage. Just below the outlet of the lake a dam site exists where a dam a little over 200 feet in length could be built to raise the water 25 feet. A large area of land would be flooded in carrying out this plan. A short distance below the outlet of the lake the river has considerable fall and makes a sharp turn to the left. A short tunnel with open cuts at the ends could easily be constructed connecting the lake with a point on the river behind this bend, where there is a difference of elevation in the water surface of 25.8 feet. The distance between these points is only 1,700 feet, and it is not probable that solid rock would be encountered in excavating. A dam from 5 to 10 feet in height could be cheaply constructed at the outlet of the lake. This would provide means for raising and lowering the lake at least 30 feet, and would give a storage capacity of about 140,000 acre-feet. This could probably be done at an expense of about $1 per acre-foot. No damages to lands bordering the lake would result from carrying out this plan.

THE SUCCOR CREEK SECTION.

The Payette-Boise project, if developed according to the plans now contemplated, will furnish a large surplus of available power in the vicinity of the diversion dam on Payette River. It is proposed that where feasible this power shall be utilized for pumping water for the irrigation of lands too high to be reached by gravity.

The small flats along Snake River furnish admirable opportunities for the utilization of a part of this power. They have splendid soil and climate, and if reclaimed will, without doubt, be among the most productive and valuable lands in southwestern Idaho. They are so situated, however, that they can not be reached from Snake River by gravity canals.

The most desirable bodies of land which it will be practicable to reclaim by pumping are situated on the south side of Snake River near the Idaho-Oregon State line, extending above and below the mouth of Succor Creek for a distance of nearly 20 miles. This area is made up of the valleys of several small creeks whose water supply is entirely inadequate for the irrigation of the land contiguous to them.

In January, 1904, the following petition, signed by 40 landowners of this locality, representing in all about 3,200 acres of land, was addressed to the Secretary of the Interior:

> We the undersigned, holders of title, or evidence of title, to lands lying along Snake River in southwestern Idaho and eastern Oregon, hereby respectfully petition the honorable Secretary of the Interior to cause an investigation of the lands lying along Snake River from the mouth of Reynolds Creek to the mouth of the Owyhee River in Oregon with a view of ascertaining the possibilities of reclaiming the same by the Government under the provisions of the reclamation act. And in the event of a feasible plan being found to reclaim these lands we hereby pledge ourselves to form any association of landowners that may be necessary in order to receive the benefit of the act, and also pledge our individual holdings for the repayment of the actual cost of reclamation.

As a result of this petition the district engineer was directed to make an investigation of the irrigation possibilities of the locality. This was done along with similar work in the Boise Valley during the past field season, and it was found that about 14,000 acres of these lands lie at an elevation of from 35 to 80 feet above Snake River, the remainder of the tract, about 10,000 acres, extending to a level 100 feet higher. There are only two sources of water supply in the vicinity which are adequate for the irrigation of all the land in this locality, namely, Owyhee and Snake rivers.

A reconnaissance survey was made by Fred Stockton to determine the feasibility of using the waters of Owyhee River on these lands. Mr. Stockton's investigation was confined to the lower portion of this stream, beginning at an elevation commanding the irrigation of the major portion of the land. The flood water of the stream can be stored at a point about 80 miles above its mouth, where Crooked Creek comes in. Mr. Stockton made no examination of this site, but from private surveys which had been made not very long ago it was found that a masonry dam 120 feet high and 300 feet long on top could be built, which would impound more than 300,000 acre-feet of water, or more than enough to irrigate all the land that can be reached from this source.

Mr. Stockton states that the point of diversion to reach these lands would be in a canyon near Malheur Butte, about 15 miles above the mouth of Owyhee River. This place presents facilities for very substantial dam construction. Bed rock does not show in the river, but the walls of the canyon indicate that it will be found at a reasonable depth below the river gravel. The abutments are of solid rock and are steep, extending far above the crest of the dam.

A dam about 140 feet in height will be required at this point, since the land to be irrigated is all below a narrow, rocky canyon on the river, and lies mostly on rather high benches. The lowlands on the north and west are already provided with irrigation facilities, being under the Owyhee ditch; in fact, practically all of the lands lying on the north and west side of Owyhee River are included in the Malheur project, it being feasible to reclaim them from Malheur River.

Beginning at the dam site, on the south side, the canal line would run down the river a distance of about 5 miles before reaching any irrigable lands. In this distance there would be considerable rockwork and some very expensive earthwork. About 6,000 acres of land could then be covered, but immediately after passing this land the canal line would encounter more rock, and where it reaches a point near Succor Creek would require considerable steep hillside excavating. Beyond this point about 12,000 acres could be reclaimed.

To make sure there were no passes through the mountain ridge between Owyhee River and Succor Creek, the summit was followed for several miles above the dam site with an aneroid, observations being taken in all the saddles and low gaps. None of them could be considered as possible crossings for a canal line.

No attempt has been made to prepare an estimate of the items of cost for this east-side canal, but when it is considered that the total length of the line would be about 35 miles, with considerable hillside and some extremely expensive rockwork, and that a diverting dam 140 feet in height, also a reservoir dam 120 feet in height, would have to be constructed, it is obvious that the cost of reclaiming this tract from this source will necessarily be very great.

A private enterprise contemplated reclaiming the lands referred to, together with a large body of land lying north of Owyhee River, but since the latter lands are under the Malheur project the cost of the work just described would necessarily have to be borne by the Succor Creek lands alone.

An investigation was also made by the Reclamation Service looking to the irrigation of these lands by means of a pumping system, the water to be furnished by Snake River. The most feasible plan in this connection is that of utilizing the power which could be created at the diversion dam on Payette River. Favorable conditions for a pumping station exist about 2 miles below Froman's ferry. From this point from 12,000 to 14,000 acres of land can be irrigated by means of a pumping plant, the water to be lifted to a height of from 50 to 85 feet.

Investigations made by the Geological Survey during the last two years indicate that Succor Creek will furnish enough water, if all impounded, for the reclamation of from 6,000 to 8,000 acres of land. A project has been under consideration for some time past by private parties for the utilization of this water on lands bordering the river. The landowners, however, have not been giving much encouragement to this project, but are anxious to have the land reclaimed by the Government in connection with the Payette-Boise project. Their views on this matter are clearly set forth in the following petition, addressed to the Secretary of the Interior during the month of September, 1904:

> We, the undersigned, owners of title or evidence of title to lands on the south side of Snake River in the vicinity of Succor Creek, Idaho, do hereby petition you to cause the chief engineer of the Reclamation Service to have an investigation made with a view of ascertaining the feasibility of reclaiming our lands by some practicable means. It is our belief that the lower lands bordering the river in this locality can be irrigated either by means of a canal diverted from the Owyhee River or by means of a pumping plant lifting the water from Snake River at a point about 2 miles above Froman's ferry.
>
> Private parties have lately been promoting a project for the reclamation of certain lands in this locality, proposing to use the water of Succor Creek for the purpose. It is a well-known fact that the water supply from Succor Creek is not sufficient to irrigate all the lands tributary thereto, and it is not our wish to make any arrangements for the utilization of these waters until it has been ascertained whether or not the lands can be irrigated from another source. Should it be found feasible to irrigate the lands bordering Snake River by pumping water from the same, then the meager supply of water from Succor Creek could easily be applied to higher lands, thus turning to good account all the available resources of this locality. Should an effort be made, however, to apply the water of Succor Creek to the lands immediately adjacent to Snake River, then it might not be feasible to reclaim any of the higher lands or utilize the waters of Snake River or the Owyhee River to advantage.
>
> Should it be found feasible to reclaim our lands through the utilization of the waters of Snake River, then we would ask that this project be made a part of the Payette-Boise project; but should it be found more practicable to irrigate our lands by means of water from Owyhee River, then we would ask that the reclamation of these lands be made a part of the Malheur project.

At a meeting held September 3, 1904, this petition was amended as follows:

> By resolution of a meeting of landowners held at the Succor Creek schoolhouse on the 3d day of September, 1904, this petition is amended so as to ask the chief engineer of the Reclamation Service to investigate the possibilities of using the waters of Succor Creek on land not capable of being watered from other sources, and the petition as so amended is approved.
>
> F. E. TRACY, *Chairman.*
> OTTO G. REINHARDT, *Secretary.*

The above petition was signed by 58 landowners, representing 8,900 acres of land. These petitioners call attention to the desirability of using the surplus waters of Succor Creek on lands which can not be reached by pumping from Snake River. Their position in this particular is obviously correct, as in this way all the irrigation possibilities could be fully utilized to the best advantage.

A third petition has recently been circulated and signed by the owners of land in the vicinity of Squaw Creek, a section farther up Snake River, asking that their lands be reclaimed in conjunction with the Payette-Boise project. It was signed by 41 landowners, representing 5,155 acres of land, and ran as follows:

> We, the undersigned, owners of land lying on the south side of Snake River, in Owyhee County, State of Idaho, desirous of obtaining the largest possible development of this section through irrigation works, and believing that end can best be attained through cooperation with the National Government in the building of works under the terms of the reclamation act, hereby petition the honorable Secretary of the Interior to have surveys and investigations made by the Reclamation Service for the purpose of determining the best means for the irrigation of these lands in conjunction with the Payette-Boise project or in any other way by Government works. We pledge ourselves to enter into such contracts with the Government as may be required to receive the benefits of the act, and to repay to the Government the actual cost of the benefits received.

Investigations are now being made looking into the feasibility of reclaiming the lands referred to in the above petition. It is thought that the major portion of them at least can be reclaimed from this source.

Investigations are also being made of the storage possibilities on Succor Creek, and it is hoped that most of the flood run-off of that stream can be utilized for the irrigation of lands lying above the 85-foot lift of the pumping system. The supply from this source will be rather meager, but by taking it up along with the rest it will be one continuous project, and, it seems, would utilize to the best advantage the natural resources at hand for this development.

Should the reclamation of these lands be undertaken as a part of the Payette-Boise project, the power for pumping will be cheap. The transmission line will be about 25 miles in length, the water supply will always remain unquestioned, and the canal construction and distribution will be easy and effective.

SUMMARY.

The surveys which have been made will serve as a basis for the preliminary location of all of the principal canals and for an approximate estimate of cost of construction. The detail surveys referred to will furnish data for the designing of all diversion works, dams, and other principal structures. As soon as the field work is finished these estimates of cost and plans of structures will be prepared, and a complete and detailed report will be prepared ready to be submitted for the consideration of a project board. It is hoped this report will be ready in the early part of January, 1905.

DUBOIS PROJECT.

SURVEYS.

The preliminary surveys made at the upper end of Snake River Valley during the latter part of the field season of 1903 indicated the feasibility of diverting water from North Fork of Snake River at a point near St. Anthony onto a large body of desert land lying west of Dubois. There are 300,000 or 400,000 acres in this tract, and fully 200,000 acres of first-class land lying in one body can be irrigated from the system of canals surveyed. It was well known, however, at the time of making these surveys that the supply of water furnished by the natural flow of the North Fork would not be sufficient, but would have to be supplemented by reservoirs. As soon as the practicability of diverting the water onto the lands was determined investigations were begun looking into the storage facilities existing on North Fork and its tributaries. These investigations were continued as late in 1903 as the weather would permit, and their results will be found in the Second Annual Report of the Reclamation Service, pages 279–282.

Early in June, 1904, a field party was organized under the direction of James G. Camp, assistant engineer, and the surveys which he began the year before were continued. These field operations were finished October 9, but none of the surveys have been plotted, nor have accurate estimates been made of the capacities of the many basins examined.

The following is a brief summary of the work done by Mr. Camp:

Reservoirs on upper Snake River tributaries surveyed in 1904.

Flat Rock	North Fork of Snake River.
Island Park	Do.
Lewis and Shoshone lakes	South Fork of Snake River.
Aster Creek	Do.
Beulah and Herring lakes	East Fork of Fall River.
Beulah Meadows	West Fork of Fall River.
Eagle Meadows	East and West forks of Fall River.

Grassy Lake	Branch of Fall River.
Willow Flat	Fall River.
Mountain Ash	Mountain Ash Creek and Fall River.
Meadow Lake	Fall River.
Loon Lake	Boone Creek.
Upper Boone Creek	Do.
Lower Boone Creek	Do.
Squirrel Meadows	Mile south of Boone Creek.
Teton	Teton River.

A survey was made from a point on Lewis River, below Lewis Lake, looking into the feasibility of diverting water from this stream into the drainage of Fall River. It was found that by constructing a dam on Lewis River about 40 feet in height Lewis and Shoshone lakes could be converted into reservoirs and the water carried to a point on Beulah Creek about 4 miles above Beulah Lake by means of a ditch less than 13 miles in length, and conducted from this lake through a chain of reservoirs to the lower Boone Creek reservoir, which is situated at the forks of Boone Creek. Mr. Camp reports that the construction of this ditch will not be difficult. If this plan can be carried out the water supply of Fall River will be very greatly increased.

Mr. Camp estimates the total capacity of the reservoirs referred to at 1,815,000 acre-feet, which greatly exceeds the volume of water available for storage. Since only about 700,000 acre-feet capacity is needed for the Dubois project the feasibility of the undertaking, from a storage standpoint, would seem to be assured. Should further investigations confirm the conclusions reached from a preliminary study of the plan to divert the Lewis River into this drainage there will be no question whatever as to the sufficiency of the water supply for all the lands whose irrigation will depend upon the North Fork of Snake River. It may even be feasible to reclaim a larger acreage under the proposed Dubois system than was at first planned.

Besides making surveys of these reservoir basins Mr. Camp looked into the power facilities on several streams in that region. A great many falls exist, many very favorably situated for the development of water power. Many of these facilities can be developed and utilized in connection with the irrigation development of the lands lower down the valley. The withdrawal of several tracts of land, including these power sites, has been recommended. Nearly all of the important reservoir sites in the Fall River drainage are situated within the boundaries of the Yellowstone National Park.

Mr. Camp reports that the water which can be stored in the Teton reservoir site can be diverted into the North Fork of Snake River at a point above the proposed diversion of the Dubois canal, and can be used to supply the lands situated in the lower valley of the Teton

River. It would thus be possible for the settlers of the upper valley to exchange water rights and by this means be benefited by the construction of this reservoir.

CONSTRUCTION.

While it would appear that this project is entirely feasible it is not important that it be taken up at once. A very large expense will be involved, perhaps from $4,000,000 to $5,000,000. All the lands are now vacant and will doubtless remain so until it is finally decided to take further action in the matter. Just at present the interests of the southwestern portion of the State deserve attention by the Government, and for that reason it is thought best to defer further action in connection with the Dubois project until after the Payette-Boise undertaking is out of the way. Investigations will be continued in a small way, however, to cover the details of the more important engineering features involved. This work can doubtless be done without interfering in any way with other work in the State. During the present winter the information gathered by Mr. Camp will be put in proper shape and preliminary estimates of capacities and cost of the entire project will be made.

POWER DEVELOPMENT ON SNAKE RIVER.

In the discussion of power development on Snake River only the water supply or discharge during the low water, or during the latter part of the irrigation season, will be considered. This is important, however, since the consummation of certain plans for the development of water power which have been under way for some time will, it is believed, seriously interfere with irrigation development of the valley. These plans contemplate the acquisition of prior water rights at spots below that at which it is proposed to divert the whole low-water flow of the Snake for irrigating the Minidoka and Twin Falls tracts.

PRESENT WATER SUPPLY.

The popular idea regarding the water supply of the Snake River is that it is inexhaustible. The general public usually view it at points where it is crossed by the railroad. Most of these crossings are below all diversions for irrigation. At these points, especially at and below American Falls, a comparatively large volume is seen flowing at all seasons of the year, and this volume is found to have actually increased as the western line of the State is reached. It is not generally known by travelers that during August and September of the past four seasons all the water in the river has been diverted for irrigation in the upper valley, leaving its bed practically dry for several miles above the mouth of Blackfoot River. This is concealed at American Falls by the fact that a supply of 2,100 second-feet, furnished by springs, reaches the river a few miles above, leaving the impression on the mind of the casual observer that there is a plentiful supply for irrigation in the upper valley.

The springs above American Falls constitute one of the sources of supply of the lower Snake River. Other supplies are derived from large springs that break out of the north wall of the canyon at an elevation of from 25 to 180 feet above the river at a spot a short distance below Twin Falls, more than 90 miles below the American Falls. These occur between Twin Falls and the mouth of Malade River, within a distance of about 50 miles, increasing in volume as the latter point is reached. Their discharge was measured by J. D. Stannard, in April, when the total amount was found to be 3,743 second-feet. The discharge of springs near the mouth of Malade River amounts to 1,090 second-feet, making a total of 4,833 second-feet flowing into Snake River between Twin Falls and this point. Many of these springs discharge great volumes, several as much as 100 second-feet each; one a mile below Lewis Ferry discharges 429 second-feet.

Only a small part of the water discharged from these springs above Hagerman Valley can be used for irrigation, as they occur only along a narrow fringe of land bordering on the river, not more than 3,000 or 4,000 acres all told, and they issue from the canyon wall from 200 to 400 feet below the surface of the great plateau, thus giving little opportunity for utilizing them for the irrigation of other lands. Part of the discharge from the springs near the mouth of Malade River will be used on the opposite side of Snake River in the irrigation of from 10,000 to 12,000 acres of land lying just above Glenns Ferry. The springs in the vicinity of Hagerman Valley will be used for the irrigation of about 8,000 acres of land in that locality. It is doubtful if more than 500 second-feet of the total volume discharged will ever be used for irrigation. This would leave fully 4,300 second-feet available for power purposes, and this should be the amount flowing in Snake River below all irrigation when every drop of water flowing above Shoshone Falls shall have been diverted for this purpose.

The river throughout this section flows at the bottom of a deep canyon, where there are many good dam sites; and in view of the facts that no irrigation right can ever interfere with the rights to use this water for power purposes, that it is discharged from heights of 25 to 180 feet above the river and passes over a dozen falls and rapids in the river itself, and that as many more could easily be created, it is very doubtful if better facilities exist anywhere in the West to-day for the development of abundant and cheap power than can be found on this section of Snake River.

The mean flow of the river from about August 15 to September 15 during the last four years has been about 2,400 second-feet. Measurements indicate that about 7,000 second-feet enter the upper Snake River Valley, all of which is diverted for irrigation above the mouth of Blackfoot River. From this point the river is dry for a distance of about 5 miles; then the springs of the Fort Hall Bottoms contribute a flow of about 2,400 second-feet at American Falls, this being the mean during the low period referred to. From American Falls to Montgomery Ferry the discharge is practically uniform. but from the latter point to Shoshone Falls there is a loss of 196 second-feet, as shown by measurements made September 1, 1902, by the United States Geological Survey. From Shoshone Falls for a distance of nearly 40 miles the flow is again augmented by springs, the discharge in the region of the Thousand Springs being about 5,900 second-feet. This is again increased by the discharge of the springs at the mouth of Malade River to a little over 7,000 second-feet, which flow continues without change to the west line of the State.

After the full development of the irrigation resources of the lower valley of Snake River about 3,000 second-feet of stored water will have to be provided to supplement the natural supply for the late irrigation of the Minidoka and Twin Falls tracts. This would increase the discharge at the upper end of the valley to 10,000 second-feet. The flow near the mouth of the Blackfoot River would then be 3,000 second-feet, while at American Falls it would be 5,400 second-feet. At Minidoka 2,000 second-feet of the stored supply would be diverted for irrigation, which would leave 3,400 second-feet flowing in the river, all of which would be diverted at Milner for the irrigation of the Twin Falls tract. Below this point of diversion the river would be dry as far as Shoshone Falls, a distance of nearly 30 miles. At the Thousand Springs, however, about 3,800 second-feet would enter the river, 250 feet of which would probably be used for irrigation in Hagerman Valley. Another increase would occur at the mouth of Malade River from the surplus flow of about 800 feet, which would join the river after the diversion of 250 feet for the irrigation of the Glenns Ferry tract has been made. From this point on the river would have a discharge of about 4,300 second-feet, practically none of which can ever be diverted for irrigation.

IRRIGABLE LANDS IN THE LOWER VALLEY.

There are two large bodies of land in lower Snake River Valley whose irrigation is feasible. The first of these is the Minidoka tract, with an area of from 130,000 to 150,000 acres. The other is the Twin Falls tract, with an area of 240,000 acres of irrigable lands. There are a few scattered tracts farther west, but they are small and, as has been explained, their irrigation will not depend upon the flow of the river above Shoshone Falls.

WATER REQUIRED FOR IRRIGATION IN THE LOWER VALLEY.

The canals for the irrigation of the Twin Falls tract, whose construction is now in progress, will have a total capacity of 3,400 second-feet. In addition, about 2,000 second-feet will be required for the irrigation of the Minidoka tract, making a total of 5,400 second-feet, which will be an average rate of 1 second-foot to each 72 acres of land. This will be a higher average duty of water than has ever been attained in Idaho, but it will probably be ample during the latter part of the season, as a large percentage of the land will be sown to grain, whose last irrigation will occur about the middle of July.

STORAGE ON NORTH AND SOUTH FORKS.

Investigations made to date by the Reclamation Service indicate the feasibility of storing from 500,000 to 700,000 acre-feet of water on North Fork of Snake River and its tributaries, and from 700,000 to 900,000 on South Fork. All the storage facilities of the North Fork basin that can ever be developed will be utilized in the irrigation of the lands of the upper valley situated above the mouth of South Fork and the lands lying west of Dubois. It might be added that practically the entire run-off will also be required for this purpose. The area which will have to be irrigated from this source is about 350,000 acres. The storage facilities of South Fork and its tributaries will be utilized in irrigating lands of the upper valley situated below the mouth of this stream, amounting to about 450,000 acres, and lands in the lower valley amounting to about 390,000 acres, or a total area of 840,000 acres.

These areas, together with a few scattered tracts, mostly on the headwaters, amount to about 1,250,000 acres, all of which will have to be irrigated from Snake River. Of this area not more than 275,000 acres, all in the upper valley, are at present under cultivation. As has been previously explained, all the water of this river has for four seasons past been diverted in irrigating this area. About 150,000 acres can be irrigated in the lower valley from the natural flow of the river. This would leave 825,000 acres, or nearly 70 per cent of the irrigable lands of Snake River Valley, whose late water supply would have to be furnished from reservoirs. If it should be discovered upon further investigation that other large areas can be irrigated from Snake River, not only the sufficiency of storage capacity but the sufficiency of the run-off itself would have to be seriously considered.

PRESENT POWER DEVELOPMENT.

Two power plants of considerable magnitude are already installed on Snake River at American Falls and at Swan Falls. (Pl. XXVI.)

The first of these plants is capable of generating about 2,000 electrical horsepower, and furnishes light and power to the towns of Pocatello and Blackfoot. The plant at Swan Falls, which is capable of generating 1,700 horsepower, transmits its power to the mines at Silver City. Both plants could be easily enlarged.

The plant at American Falls can never interfere with the irrigation development of the Snake River Valley. The minimum discharge of the river at these falls is about 2,100 second-feet, none of which can be diverted until it reaches Minidoka. This supply will never be diminished, and will be greatly increased by the use of reservoirs perhaps to as much as 5,400 second-feet during July, August, and September, depending upon the amount of water which will have to be used for the irrigation of the Minidoka and the Twin Falls tracts. The available head of this site is 47 feet.

The minimum discharge at the Swan Falls power site will be about 4,300 second-feet after all the water in the river shall have been diverted for the irrigation of the two tracts referred to. The head is 17 feet.

PLANS FOR FURTHER DEVELOPMENT OF POWER.

Plans which contemplate the development of power at other points on this river have been inspired chiefly by the prospect of early development of the irrigation possibilities of the lower valley. They have not advanced to a point where, under ordinary conditions, they would be regarded seriously, but owing to the relation which they may bear to the irrigation interests of practically the entire Snake River Valley, they deserve very serious consideration, for the reason that the sites chosen for their location are below the head of the Twin Falls system, and are thus on the section of the river which will be practically dry for three months out of the year when the Minidoka and Twin Falls tracts are supplied with water for irrigation. Their development is a menace to irrigation interests, because the water rights which the promoters of these projects are seeking to establish may be prior to the irrigation rights of either of these tracts. If the plans are carried out on the lines contemplated, it may be necessary to utilize nearly one-half of the storage facilites of South Fork of Snake River in satisfying power rights, the water so supplied passing on down the river uselessly to the sea, because it can not be diverted below the power sites.

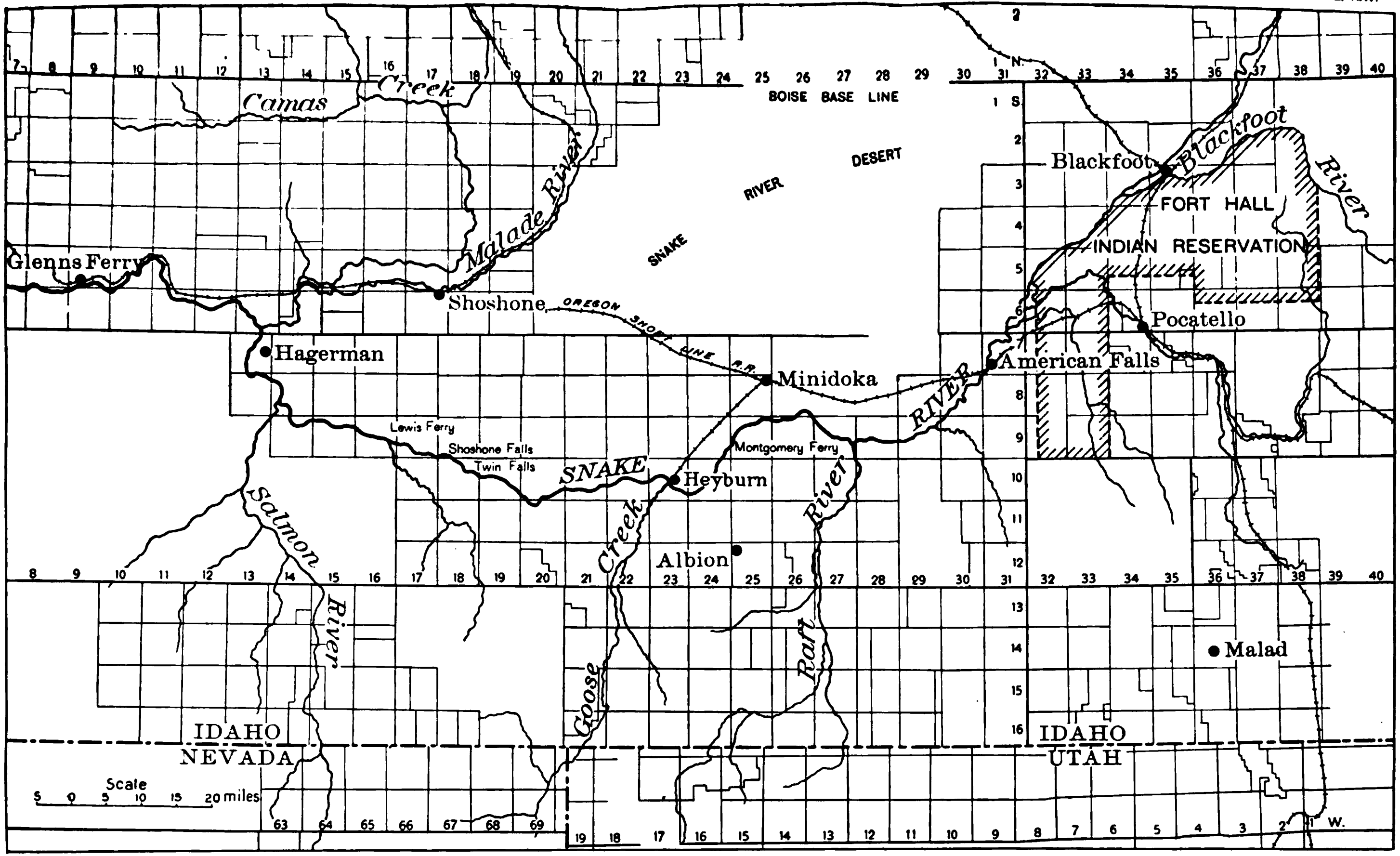
Practically all of the power development plans appear to revolve about two principal sites, the Twin Falls and Shoshone Falls, which are about 22 to 25 miles, respectively, below the point of diversion of the Twin Falls canal system. The river at Twin Falls makes a vertical drop of about 180 feet, and at Shoshone Falls of about 203 feet. An excellent site exists at the latter place for the cheap development of power, it being possible to divert the river above the falls and lead the water onto wheels by means of a tunnel about 400 feet in length. A good site for a power house exists at this point. A good site also exists at Twin Falls for the development of power. But while at American Falls there will be almost a uniform minimum flow during both summer and winter of over 5,000 second-feet, even after irrigation has been fully developed in the valley below, at Shoshone Falls, after this degree of development shall have been attained, the river will be dry during three months of nearly every irrigating season.

WATER RIGHTS.

Work has been done at both of these places for the purpose of establishing claims which have been made to water for power purposes. This work was begun at Shoshone in October, 1901, first by making surveys and plans, and early in the following December by actual construction work on a tunnel 12 by 12 feet, designed to divert the river above the falls. This work has been in progress from time to time ever since, the tunnel now being in to within 100 feet of the head-gate. A small tunnel driven through the rock below Twin Falls on the south side of the river now taps the river above the falls.

The promoters of these projects have been actively at work for the past two or three years endeavoring to raise the necessary capital for their prosecution, and already a considerable amount has been involved. It is stoutly maintained by those interested in this work that the rights to the water for power purposes are prior to the irrigation rights in this vicinity, it being asserted that the irrigation right for the Twin Falls tract, claimed October 11, 1900, lapsed by reason of the fact that actual construction on that enterprise did not begin until March, 1903.

The following table shows the claims which have been made to the water of the Snake River in this vicinity from the date of filing of the claims made by the Twin Falls Land and Water Company to the application for permit to appropriate water for irrigation of the Minidoka tract:



MAP OF PART OF SNAKE RIVER VALLEY, IDAHO, SHOWING LOCATION OF POWER PLANTS.

Claims to water of Snake River, near Shoshone Falls, from October 11, 1900, to March 26, 1903.

Name of claimant.	Date of claim.	Amount in second-feet.	Purpose.	Place of use.
Twin Falls Land and Water Co.	Oct. 11, 1900	3,400	Irrigation....	Twin Falls tract.
I. B. Perrin..........	Nov. 1, 1901	1,000	Power.......	Shoshone Falls.
A. Z. Conrad.........	Sept. 13, 1902	1,000	.....do	Do.
J. J. Blow............	Sept. 22, 1902	4,000	.....do	Twin Falls.
J. H. Robertson.....	Sept. 24, 1902	3,000	.....do	Do.
A. Z. Conrad.........	Dec. 10, 1902	4,000	.....do	Do.
Francis M. Lyman[a]..	Mar. 25, 1903	3,000	.....do	Shoshone Falls.
Secretary of Interior.	Mar. 26, 1903	2,600	Irrigation....	Minidoka tract.

[a] Permit not granted; matter in court.

From the above table it will be seen that the claims for irrigation and power purposes, not counting those made at Twin Falls, aggregate 8,400 second-feet. The claims made at Twin Falls may be ignored, as no attempt has ever been made to comply with the law; and, besides, all the rights which could ever be perfected at Shoshone Falls would be available at this point. The first two claims made at Shoshone Falls initiate the right which it is proposed to perfect, if possible, and which would conflict with all the irrigation rights in the lower valley; and, if they should be perfected for the amount claimed, would ultimately involve the majority of rights in the upper valley as well. For should the plans now in contemplation be carried out, and these rights be given priority over the irrigation rights of the lower valley, in order to irrigate the lands of this section more water would have to be stored for the purpose than would be required if the irrigation rights stood first; for both rights could be satisfied only by storing more water. But all the facilities for storage will, without doubt, be required for the complete irrigation of the lands of the upper and lower valleys.

There is no local market for the power which it is proposed to develop, but plans are being made by the promoters of this project to transmit power to Salt Lake Valley. This could be profitably done only on a large scale, which would require a large investment of capital. Should the plan be consummated many powerful interests in distant communities would then be involved, which would, of course, be opposed to the irrigators of Idaho when the conflict over water rights occurs. What this means to Idaho would be better understood if it were proposed to divert 1,000 to 2,000 second-feet of the water of the Snake River during its low stage over into the Salt Lake Valley, to be used there regardless of the rights or interests of the people of the Snake River Valley.

PROTECTION OF IRRIGATION RIGHTS.

It should be seen from the foregoing that it would not be sound public policy to permit the utilization of the waters of Snake River, and indirectly its storage facilities, for purposes other than irrigation. The possible conflict of interests, which has been explained, could easily be avoided if advantage were taken of the splendid facilities for power development which exist at points on Snake River between the upper and lower valley, or the many points below Shoshone Falls.

The work contemplated at the latter place is being pushed forward regardless of the conditions above explained, and evidently without any regard for the best interests of the people of Idaho. The ease with which a very valuable water right can be established and developed, and a large power plant installed at this place when needed, is the attractive feature of this site. The prospect of an early local demand for power through the development by irrigation of a vast area in the immediate vicinity, and the possibility of marketing a large amount of power in an old and well-developed community, may tempt an unwary capitalist to invest in this enterprise. Should irrigation development in that vicinity be long delayed, the water rights which are claimed at this point may be easily perfected and become firmly established, for not until the actual and pressing need for water is realized by the irrigator in that portion of the valley is any step likely to be taken by the people themselves for the protection of irrigation rights. By that time the mischief will have been done, and it is doubtful if the conflicting interests could be adjusted without great detriment to the agricultural interests of the Snake River Valley.

There is, perhaps, only one certain means of insuring the undisputed and unquestioned priority of irrigation rights in this section, and that is through the condemnation by Idaho of all water rights sought to be acquired which would in any way interfere with irrigation development.

The constitution of Idaho contains a provision which would, without doubt, render such an adjustment feasible. Section 3, article 15, provides that—

> The right to divert and appropriate the unappropriated water of any natural stream to beneficial uses shall never be denied. Priority of appropriation shall give the better right as between those using the water; but when the waters of any natural stream are not sufficient for the service of all those desiring the use of the same, those using the water for domestic purposes shall (subject to such limitations as may be prescribed by law) have the preference over those using

the same for manufacturing purposes. And in any organized mining district those using the water for mining purposes or milling purposes connected with mining shall have preference over those using the same for manufacturing or agricultural purposes. But the usage by such subsequent appropriators shall be subject to such provisions of law regulating the taking of private property for public and private use as referred to in section 14 of article 1 of this constitution.

Authority would exist under this provision to exercise the right of eminent domain as a means of setting aside the priority of the inferior right to use of water for power purposes at Shoshone Falls by making such right second to the superior irrigation right.

The adjusting of rights in this way will, without doubt, be necessary in order to protect the Minidoka project, and it may be necessary in order to give the lands of the Twin Falls tract a first right to the use of this water. The only other way of providing for all these rights in accordance with the priority which may be established is to allow the amount of water claimed for power purposes to flow past the head-gates of these great canals undiminished and make good this amount by storage; but unfortunately this plan could be carried out only by sacrificing a large share of the agricultural possibilities of the State, for the reason that there is not sufficient storage capacity to permit of this extravagant use of water.

FORT HALL INDIAN RESERVATION.

IRRIGABLE LANDS.

The irrigable lands of the Fort Hall Reservation are situated in Snake River Valley between Blackfoot River and American Falls. They comprise an area estimated at from 90,000 to 120,000 acres. This tract lies in a very compact body, bounded on the east and south by a well-defined range of foothills and on the northwest by Snake River.

PRESENT IRRIGATION FACILITIES.

The reservation canal, which diverts water from Snake River near Basalt, skirts the foothills on the east, terminating at Ross Fork, and is the only means at present for irrigating these lands. This canal was constructed by the Idaho Canal Company, at the expense of the Government, and was designed for the irrigation of the Indian lands, for which purpose it is used to-day, water being distributed through it for irrigation as far as Ross Fork, irrigating about 1,500 acres.

WATER SUPPLY.

Water is supplied to this canal by Snake River, and considering the date of this diversion and the discharge of this stream, the water right should be good compared with other rights on the river, provided too long a time does not elapse before the water shall be beneficially applied to the use for which it was intended.

Suit was recently filed in the district court for the allotment of the waters of Snake River and for establishing the priority of the rights of the many canal diversions. The following provision, which appears in the law of this State, will be the basis for this allotment:

> SEC. 38. In allotting the waters of any stream by the district court according to the rights and priorities of those using such waters, such allotments shall be made to the use to which such water is beneficially applied, and when such water is used for irrigation the rights confirmed by such decrees or allotment shall be appurtenant to and shall become a part of the land which is irrigated by such water, and such decree shall describe the lands to which such water shall become appurtenant. And the amount of water so allotted shall never be in excess of the amount actually used for beneficial purposes for which such right is claimed: *Provided*, That in the case of works capable of diverting more water than is applied to a beneficial purpose at the time the rights of the person or persons owning or using such works are adjudicated by the court, the right only to the water beneficially applied at the time of making such allotment shall be confirmed by the court, and the court shall ascertain the amount of water which can be diverted through such works in excess of such quantity beneficially applied, and shall set a time when such amount shall be applied to the beneficial purpose for which it is intended, which time shall not exceed four years from date of the decree issued by the court under such adjudication, and any person using any such water shall, before expiration of the time set for such beneficial application, make proof of such right, when confirmed in the manner provided in this act shall relate to the priority established by such court, and if such application of any of such water shall be made subsequent to such date, then the priority of the right to the use thereof shall be determined in the manner provided in section 8 of this act.

Applying this provision of the State law to the case of the reservation canal, its capacity at the time of this allotment fixed also the quantity of water beneficially applied at that time. In order to secure a right bearing priority all of the water would have to be beneficially applied within four years from the date of allotment.

There is no doubt that this canal would be entitled to divert 300 second-feet of water during practically the entire irrigating season if the right should be perfected through beneficial use. But only a small part of the 300 second-feet is used at present, the rest wasting back into the river, and there is great danger that the Indians will not be able to apply the full amount of water beneficially for many years to come, and the result will be that a part of the right would be lost. In that event the supply would have to be made good by storage, and water may be very scarce when the entire irrigable area on the reservation is under cultivation. At that time at least one-third of the season's supply, or perhaps about 150,000 acre-feet, may have to be furnished from reservoirs.

The storage facilities of Snake River consist of natural lakes and basins situated on the headwaters of South Fork, Fall River, and Henry Fork. While these facilities appear now to be very ample, they will all probably be needed for irrigating the large bodies of lands which may be reclaimed under the provisions of the reclamation act and for supplementing the supply for many thousands of acres under existing canals in upper Snake River Valley, which are very likely to be developed long before any necessity arises for an increased water supply for the Indian lands.

The Indians are likely to be wards of the Government for many years to come, but their irrigable lands are farther from the reservoir sites on the headwaters of these streams than any other lands in the upper valley, and it may be extremely difficult to acquire for their benefit joint ownership in one or more of these reservoirs after they have been developed and used by the people of the upper and lower valleys of Snake River.

BLACKFOOT RESERVOIR SITE.

The Blackfoot River reservoir site is situated near the head of Blackfoot River, a stream which forms part of the boundary of the reservation and one whose waters can not very well be used on other lands. It has but a small summer flow, but its annual discharge is probably sufficient to supplement the early flow of Snake River and furnish an abundant supply for the late irrigation of all the lands that are ever likely to be cultivated on the reservation. The chief value of this site lies in the fact that it is close to the reservation and can easily be made a part of a system for irrigating all these lands, including, of course, the ceded lands. It could be developed and administered for the exclusive benefit of these lands without conflicting with the right of other portions of Snake River Valley, and it could be utilized at any time, not depending in any way upon the development of sections outside of the reservation.

Blackfoot River site was surveyed in 1896 by Cyrus C. Babb, whose brief report will be found in the Eighteenth Annual Report of the United States Geological Survey, part 4, page 30, and was reexamined in November, 1903, by Fred Stockton, assistant engineer.

The following table shows the capacity of the basin at different contours:

Capacity of Blackfoot River reservoir site at different contours.

Contour.	Area.	Capacity between sections.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
10	1,210	6,050	6,050
20	10,915	60,625	66,675
30	14,752	128,335	195,010
40	17,623	161,875	356,885
50	20,060	188,415	545,300
Total	....	545,300	....

The capacity of the basin at the 50-foot level is much greater than will ever be required or could ever be filled from this drainage. It is estimated, however, that upwards of 150,000 acre-feet of stored water will one day be needed on these Indian lands. Information regarding the run-off from this stream is not very complete, but it is safe to estimate that at least 150,000 acre-feet are available. To store this amount of water would require a dam about 30 feet high and would cost about $50,000.

The valley that would be flooded by this reservoir is bounded by hills. These hills are covered by a sandy soil through which very little lava outcrops, especially below a shore line that would be 30 feet above the bottom of the reservoir. On the south side near the dam site the shore line would be just below a bluff, which is evidently formed of lava. Toward the upper end of the reservoir site there are some rather choppy lavas, but these do not extend over very large areas that would be below the shore line.

The drainage area tributary to the basin is 666 square miles. The run-off can be estimated only from measurements taken at a regular station near Presto, which has been maintained only since last March. During that time the maximum discharge was found to be 300 second-feet on April 27. The minimum was 139 second-feet and was constant during the month of August. The total run-off for the year may be estimated from these measurements at about 120,000 acre-feet, but the discharge for this year is without doubt considerably below the average.

A 30-foot dam would be sufficient to hold all the water of Blackfoot River available for storage, unless it be an exceptionally high-water year.

There seems also to be a possibility of diverting the waters of Grays Lake over into this reservoir, but the feasibility of this has not been investigated on the ground. Grays Lake is thought to be considerably higher than a tributary of Blackfoot River not over 2 miles from it. The divide between the two is said to be rather low, consisting in most places of two small ridges instead of a single high, well-defined one.

Just over this divide from Grays Lake is a rather large spring, called Chub Spring, tributary to Blackfoot River. This spring is generally believed to head in Grays Lake. During the summer the water from the spring becomes very much warmer than during the winter and has the taste and peculiar reddish appearance of the lake water.

If this supposition is found to be correct it will be very difficult to store water in Grays Lake. If, on the other hand, this water can all be thrown over into one reservoir the evaporation surface will not be so great and the water supply for the Indian reservation will be increased. The drainage area tributary to Grays Lake is about 125 square miles, and the run-off for 1904, estimated from measurements taken on Willow Creek, near Presto, since March, will probably reach 50,000 acre-feet. This, added to the 120,000 acre-feet of Blackfoot River, gives 170,000 acre-feet as the combined discharge for a low-water year.

The dam site is at a place commonly called the " Narrows," 7 or 8 miles below the main part of the basin, but this does not detract materially from the value of this site for a reservoir, for the portion of the river between the dam site and the main part of the basin is very deep and sluggish, there being not over 2 feet fall to the mile. The difference in elevation of the river at the dam site and at the reservoir is not over 15 or 16 feet.

The formation at the dam site is volcanic. The left bank is a solid wall of lava and the right shows large rocks of broken lava. In both banks the lava is covered with soil. The channel presents a firm bed of gravel. If a solid bed of lava is found beneath this gravel across the channel a solid masonry dam might be built on it as a foundation. But if the gravel extends far down, a rock-fill dam can be very economically built. The material could be taken from the outlet to the reservoir, which would probably be an open cut in the lava bank, and from the spillway. The contour map shows a steep slope that comes down near the river on the left bank; this slope is well defined and extends several miles back to the higher hills. The right bank slopes more gradually, but has no gaps that would come below a 50-foot contour. The water that would be stored in this reservoir could all be used on the lands of the Fort Hall Indian Reservation.

The control of this site by the Government practically insures the water supply for the entire irrigable area contained in the reservation, no matter what degree of development may be attained in Snake River Valley, nor how soon such may occur, nor how long the full development of the Indian lands may be deferred. A complication has already been introduced in the irrigation situation on the reservation through the private ownership of the present irrigation system. It would be likely to complicate matters still more and leave the future of the Indians in doubt, and practically to chance, if this reservoir site should be given to private enterprise instead of being held as a part of a system for the development of the Indian lands. Should it once pass from the hands of the Government it would not likely be again available.

KOOTENAI RIVER RECONNAISSANCE.[a]

During the last season a reconnaissance was made along Kootenai River between Crossport, Idaho, and Nelson, British Columbia (Pl. XXVII), in order to determine the practicability of reclaiming about 30,000 acres lying between Crossport and the international boundary line, which are flooded during the high stages of Kootenai River. This high stage of the river generally lasts until the latter part of June, at which time the season is too far advanced to raise anything but wild grass for hay.

At and above Crossport the stream is torrential and the banks are high and precipitous, but below Crossport it is sluggish and meanders through a valley averaging 2 miles wide. This valley is a typical flood plain, the banks being from 5 to 15 feet higher than the major part of the land lying farther back from the stream, but they are crevassed in many places and are very pervious, giving the water during the high stages of the river free access to the lower land. Between Crossport and Kootenai Lake there is only one large tributary which empties into Kootenai River in Canada, but there are at least 12 small tributaries which discharge considerable water during the high stages of the Kootenai. Therefore, considering the pervious nature of the soil and the numerous tributaries which would also have to be diked, it is not believed that it is feasible or practicable to dike the banks.

The fall of the river between Bonners Ferry, Idaho, and Kootenai Lake, a distance of 40 or 50 miles by river, is not over 16 feet (it varies between 2 and 16 feet), while the difference in elevation of Lake Kootenai between high and low stage is at least 25 feet; therefore enlarging or straightening the channel of Kootenai River (which at present averages about 15,000 square feet in cross-sectional area) would not improve matters, the stage of the lake being the chief controlling factor governing the stage of the river. The gaging station at Bonners Ferry and the gage rods set at Crossport and Porthill, Idaho, show that the lake has a greater effect on the stage of the river than the discharge.

An allotment of water to the reservation canal will be made and the order of its priority will soon be determined by the State courts. In order to perfect the rights thus recognized, the water will have to be beneficially applied within four years from the date of such allotment. There is some danger that the Indians may not be able to apply all of this water, 300-second feet, beneficially within that time. The priority of the 300-second feet not beneficially applied at that time would be affected, losing its original order.

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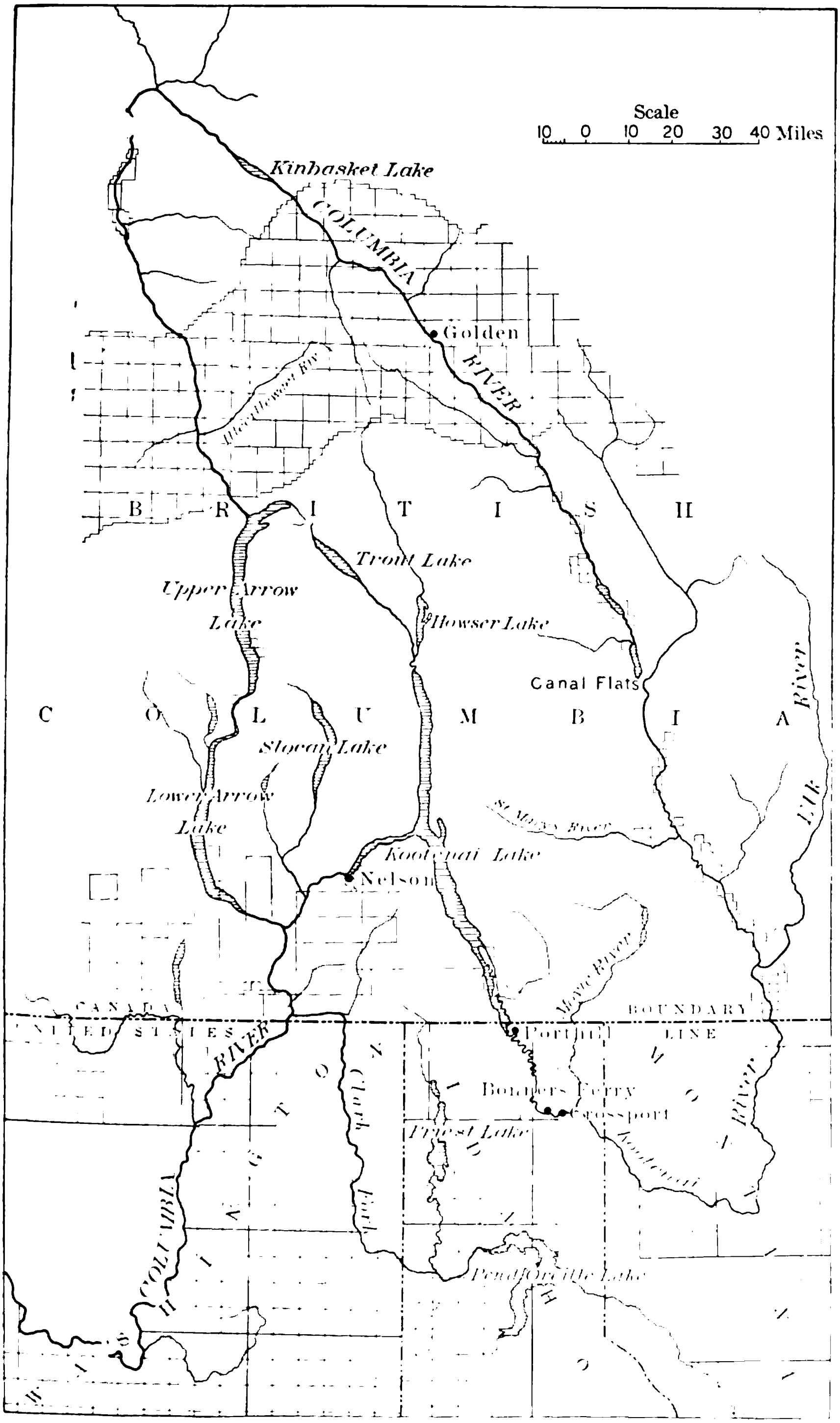
[a] From report by W. W. Schlecht.



MAP OF THE DRAINAGE BASIN OF THE UPPER COLUMBIA AND KOOTENAI RIVERS

Kootenai Lake has an area of at least 40 square miles, and with a continuous outflow it nevertheless rises about 25 feet each year; therefore a storage and regulating reservoir above Bonners Ferry would have to hold at least 500,000 acre-feet in order to reduce the high stage of the lake 10 or 15 feet, and a reservoir of this capacity would probably flood as much land as it is intended to reclaim; and if this reservoir be in the United States the land would probably be just as valuable as that near Bonners Ferry. On May 13 and 14 the Kootenai was discharging 28,953 second-feet, and was then about 20 feet below its highest stage.

There seems to be three possible ways of reclaiming the lands in question, each of which will be considered in turn: (1) By enlarging the outlet of Lake Kootenai, thus lowering the lake sufficiently to keep the lands above high water; (2) by surrounding the lands by dikes, so that the flood waters could not overflow them, and (3) by diverting Kootenai River near its headwaters at Canal Flats into Columbia River.

The first method would be expensive, since the Kootenai, for a distance of several miles from the outlet to the lake, flows through a rocky canyon with a mountain on either side. The entire river bed would have to be widened or deepened for several miles, and the cost would probably be as great as the value of the lands to be reclaimed. Further, the improvement would be on British Columbian soil, and could not be done without the consent of Canada.

The system of dikes would also be expensive. It would require 60 miles of dike to reclaim 22,000 acres of land, or 367 acres per mile of dike. Additional areas could be diked which are unsurveyed ground, but it is not probable that more than 26,000 acres could be diked. These dikes would probably have to reach a maximum height of 18 feet, and an average of 12 feet on the river side, and cost such a large sum per mile as to make the average expenditure on behalf of each acre reclaimed more than the probable value of the land.

Further, the dikes next to the river would probably not be safe. As the river spreads out over the flat, the current is sluggish and erosion is not excessive, but if confined to its low-water channel the current and the high level of the river would be increased and erosion of the banks would probably be excessive. The soil composing the deposit in the river is a sandy loam much like the silt in the Mississippi River Valley, easily eroded in a swift current. Still further, as the dikes would be entirely surrounded by high water, it would be necessary to install power pumping plants to keep out the seepage water which would collect during the sixty days when the river was high, and would also be necessary to entirely surround the individual areas within the bends of the river to keep out the water draining from the surrounding mountains into the valley and to allow passageways for these streams to the river.

The third plan seems to be more feasible. There is a possibility that the floods might be relieved by diverting the Kootenai into the headwaters of the Columbia at Canal Flats, but any improvement of this nature would require the approval of the Canadian government and would probably meet the opposition of those living along the Columbia, as there is a possibility of damage due to the increase of flood waters in the Columbia with no corresponding benefits to be derived from them.

GENERAL RECONNAISSANCES.

Besides the reconnaissance surveys made on Payette and Boise rivers, in connection with the Payette-Boise project, and those on Snake River, in connection with the Dubois project, examinations were made of the smaller tributary valleys on the north side of Snake River. These included Big and Little Wood rivers and Big and Little Lost rivers, and Birch, Medicine Lodge, and Camas creeks. Reconnaissance was also made of Deep Creek in Oneida County. The supervision of this general reconnaissance work was assigned to Fred Stockton, assistant engineer.

WOOD RIVER BASINS.

The work on Wood River basins was taken up late in May, 1904, and consisted of reconnaissance surveys for reservoir sites on Big and Little Wood rivers and their tributaries. These streams all have so much fall and the valleys are so very narrow that no first-class reservoir sites exist. The following possible sites were looked over and reported on:

Boulder Creek, on Big Wood River, near the mouth of Boulder Creek.

Eagle Creek, on Big Wood River, near the mouth of Eagle Creek.

Little Wood River, about 8 miles above Carey.

Fish Creek, east of Carey.

In the latter part of June a field party under the direction of R. J. Newell, engineer aid, began making surveys of these sites. These surveys, however, seem to indicate that the cost of storing water at these places would be so high as to be prohibitive.

BIG AND LITTLE LOST RIVERS AND NEIGHBORING CREEKS.

After completing investigations on Big and Little Wood rivers Mr. Newell proceeded to Big Lost River and made a part survey of a site at Thousand Springs Valley; also a survey of the valley above the

Narrows, about 3 miles above the town of Mackay; and another one on Antelope Creek, a tributary of Big Lost River.

The site at Thousand Springs Valley was abandoned on account of the very apparent lack of foundation for a dam, which, to flood the valley to any considerable depth, would have to be nearly 2 miles long.

The site at the Narrows gives promise of being very good for reservoir purposes. It is at that point below the sink on Big Lost River where the water is forced to the surface again, no doubt by some impervious stratum underneath, and on that account the valley above would probably be very well suited to hold water.

The site on Antelope Creek also gives promise of being suitable for reservoir purposes.

Practically all the irrigable land on Big Lost River is held in private ownership, and the waters of this stream have been allotted to the present land owners by the court. The allotment in this case is a very generous one, amounting to several times the normal flow of the stream. This has not facilitated the work of distributing the natural supply, nor had a tendency to bring about harmonious relations among the irrigators on the stream. But, notwithstanding the unsatisfactory status of water rights, there is no doubt that if the conditions at the dam site at the Narrows should be found upon further investigation to be satisfactory the construction of a reservoir at this place would greatly benefit the present irrigators.

The investigations on Little Lost River and the smaller streams to the east were carried on by a field party under the direction of J. B. Bond. In all, 7 sites were surveyed on Little Lost River, and on Birch, Medicine Lodge, Beaver, and Camas creeks. The results from these surveys are not very promising. Where dam sites with rock abutments and not excessively long crests could be obtained, they were invariably in lava, and in most cases the cost of construction, even on a good foundation, would be so great for the amount of storage developed that it could hardly be considered feasible.

DEEP CREEK.

A reconnaissance survey was made during the month of April, 1904, by Fred Stockton, of the storage facilities of Deep Creek, near Malad City, Oneida County. It was found that a capacity of about 2,000 acre-feet could be developed, but the water would be used principally as a late supply on lands held in private ownership. No public land could be reached. On this account and for the reason that the development could be effected at comparatively reasonable cost the conditions do not seem to be in keeping with the intentions of the reclamation act as it is being carried out at present, and the undertaking would probably be better handled through the agency of the local organization now existing, or under the irrigation district law

STREAM MEASUREMENTS.

During the field season of 1904 a study of the water supply of the Snake River drainage was continued, several new stations having been added for the purpose. A station was established on Big Wood River at Gimlet, and one on Little Wood River at Carey. In addition to the station established last year on Big Lost River at Mackay, which is below the sinks, another above the sinks at Chilly was added.

Besides the daily observations made at the regular stations established on Snake River and all of its principal tributaries, measurements were made during the season of the discharge of many of the upper tributaries in connection with reservoir surveys and general reconnaissances.

This work has been carried on under the general supervision of Fred Stockton, assistant engineer, who has been assisted by William G. Davies and J. B. Bond.

STATE COOPERATION.

Several important suits for the adjudication of water rights having recently been filed, it became necessary for the State engineer of Idaho to make hydrographic surveys of several of the important valleys of Snake River basin, the most important of these being Boise and upper Snake River valleys.

The survey of Boise Valley was begun during the summer of 1903 and completed in February, 1904. At the request of the State engineer, measurements were made during the month of June by the Reclamation Service of all the canals diverting water from Boise River. These measurements were made with a view of verifying measurements made the year previous under the direction of the State engineer. The following table shows the capacities of these canals:

Capacities of canals diverting water from Boise River.

Canal.	Date.	Volume by meter.	Volume at high-water mark, computed.	Capacity of finished section.
New York	June 27	173.1	183.4	
Coston	June 10	14.3		
Keogh	...do ...	.9		
Meeves	...do ...	Dry.		
Perrault	June 21	30.8		
Bubbs	June 10	44.1		
Mill ditch	...do ...	174.6		
Boise City	June 21	31.1		
Rapid Transit	...do ...	34.0		
Ridenbaugh	June 22	454.4		454.4
Davis (private)	June 11	3.8		
Davis canal	...do ...	54.8		
	June 27	76.1	83.4	

Capacity of canals diverting water from Boise River—Continued.

Canal.	Date.	Volume by meter.	Volume at high-water mark, computed.	Capacity of finished section.
Settlers	June 11	139.8		
	June 30	149.0		149.0
Thurman Mill Slough	June 27	17.0		
Valley	June 16	41.3		
Farmers' Union	do	148.7		
	June 22			
Little Union	do	50.0		
Eureka No. 1	June 13	15.1		
	June 26	Dry.		
Dry Creek	June 16	56.85		
Ballentine	June 17	19.1		
Pioneer	do	26.3		26.3
Joplin	June 26	Dry.		
Catlin	do	7.6		
Conoway	do	5.8		
Webster Slough	do	Dry.		
Middleton canal	June 17	139.01	273.9	
Middleton Slough	do	102.2		
Phyllis	June 13	156.4		
	June 26	Dry.		
Lawrence and Kennedy	June 23	([a])		
Caldwell	June 13	50.9	159.5	159.5
Strayhorn	do	2.6		
Canon County	June 15	23.2	57.7	
Masons	June 13	Dry.		
	June 25	Dry.		
Riverside	do	143.9		
Sebree	June 14	227.4		
	June 25	243.3		243.3
Campbell	June 14	2.2		
	June 24	([a])		
Siebenberg	June 15	13.7		
Keller	June 14	21.4		21.4
American	do			
	June 25	19.7	50.7	50.7
Center Point	June 14	7.3		
	June 25		17.5	17.5
Eureka No. 2	June 13	24.3		
	June 25		34.75	34.75

[a] Nearly dry.

The surveys made by the State engineer showing the irrigation development of Boise Valley will be available for use and of great value to the Reclamation Service in studying the irrigation conditions in connection with the Payette-Boise project.

The determination of the rights on upper Snake River Valley is also a matter of great importance, involving as it does the rights of ditches irrigating at present between 250,000 and 300,000 acres of land, and capable of irrigating, by enlarging and extending, upward of 700,000 acres in this valley. But before all the lands of this section can be irrigated it will be necessary to begin the construction of reservoirs on several of the main branches of Snake River. The irrigation survey of this valley now being made by the State engineer will show the present condition of development and will serve as a basis for recording all irrigation development made subsequent to the adjudication of existing rights. For this reason the results of the work now being done under his direction will all be available for use by the Reclamation Service, and will serve as a basis for determining the relation which the various irrigation communities in this valley will bear to the Minidoka and Dubois projects, and for the determination of the benefits which other portions of the upper valley will receive through the construction of storage works which the Government will doubtless be asked to undertake in the near future.

Owing to the importance of this survey and to the fact that the results will be largely used by the Reclamation Service in the near future and to the further fact that the State had made no provision for bearing the expense of such survey, the State engineer requested the Reclamation Service to share the expense of the undertaking. This suggestion was favorably received, and the following contract was entered into with the State engineer:

This agreement, made and entered into this 8th day of August, 1904, between F. H. Newell, chief engineer of the Reclamation Service, for and on behalf of the United States Geological Survey, party of the first part, and Wayne Darlington, State engineer of the State of Idaho, party of the second part, witnesseth:

Whereas the Reclamation Service, a part of the United States Geological Survey, is authorized by the act of Congress approved June 17, 1902 (32 Stat. L., 388), to make surveys and investigations of the water supply of the State of Idaho, for the irrigation of arid lands therein, and is authorized to use the reclamation fund established by said act for such purposes; and

Whereas the State engineer of the State of Idaho is engaged in a survey of the water supply of Snake River, Idaho, and the determination of said water supply is necessary for the investigations of the said Reclamation Service, in connection with irrigation works now under investigation under the provisions of the said act:

Therefore, be it agreed, That the Reclamation Service will on the submission of proper pay rolls prepared in the manner required by its rules and regulations, and certified by D. W. Ross, district engineer of said service, in charge of its work in Idaho, pay one-half of compensation due the persons actually employed upon the field and office work of such survey.

In consideration whereof the party of the second part agrees to conduct said surveys, so far as may be feasible, in accordance with the regulations of the United States Geological Survey, and to furnish promptly to said D. W. Ross, representing the party of the first part, the original or certified copies of all data obtained, and of all maps constructed, in pursuance of this agreement: *Provided,* That if originals are furnished, copies thereof shall be made by the party of the first part and promptly returned to the party of the second part. All copies of data or of maps so made or furnished to the party of the first part may be used and published by it in the usual manner, due credit to be given to the party of the second part.

The party of the second part shall cause monthly reports of the progress of the work to be made to the party of the first part, in accordance with its regulations.

The provisions of this agreement, when duly executed by and on behalf of both parties and approved by the Director of the United States Geological Survey, shall be considered as binding upon both parties from June 1, 1904, until the work now undertaken by the party of the second part shall have been completed, which is estimated as seven months from said date.

In testimony whereof the said parties have hereunto set their hands the day and year first herein written.

Executed in duplicate.

F. H. NEWELL,
Chief Engineer Reclamation Service, for and on behalf of the United States Geological Survey, party of the first part.

WAYNE DARLINGTON,
State Engineer of the State of Idaho, party of the second part.

Approved:

CHAS. D. WALCOTT,
Director of the United States Geological Survey.

It is estimated that the field work in connection with this survey will be finished at least by January 1, 1905, and that the results will be available about a month later.

In addition to bearing part of the expenses of the survey referred to, the Reclamation Service, during the irrigating season just ended, made measurements of all the canals diverting water from Snake River for use in the irrigation of these lands. These measurements were made by William G. Davies, engineering aid, in connection with his regular work of stream measurement.

Daily observations were made of the discharge of all the principal canals, the record showing the continuous discharge during the greater portion of the season. The State engineer's survey will show the area irrigated by each canal, and will thus afford a basis for very close estimates of the duty of water in this portion of the valley. The data relating to this feature will be compiled after the close of the field season.

OPERATIONS IN KANSAS.

By Charles S. Slichter.

INVESTIGATION OF THE UNDERFLOW OF THE ARKANSAS RIVER.

An investigation of the underflow of Arkansas River was begun June 11, 1904. The work consisted in accurately mapping the water plane or ground-water level for a distance of 6 to 12 miles from the river channel and in observing by the electrical method the rate of movement of the underflow. The level party consisted of Ray Owen, levelman, Frederick Thwaites, a field assistant acting as rodman. The ground-water levels were obtained by observations of the water levels in private wells on the farms in the neighborhood of the river and by observations in a few wells which were sunk especially for the purpose. The slope of the water plane was found to be between 7 and 8 feet to a mile in a general easterly direction and from 2 to 3 feet to a mile toward the river channel from the country immediately to the north and immediately to the south of the river. The southern margin of the river valley is bordered for 5 to 10 miles to the south by sand hills, only partly covered with natural vegetation, which extend from east of Dodge, Kans., to the Colorado line on the west and beyond. North of the river valley the ground rises rather abruptly to the high plains, with their well-known level topography and compact sod of native grasses. The slope of the water plane toward the channel of the river from the north is, as has been stated, about 2½ feet to a mile; however, after passing to the north for a distance of 10 to 14 miles the southward-sloping water plane changes to a northward-sloping water plane, the land at the same time gently dipping to the north toward the valley of White Woman Creek. The easterly slope of 7½ to 8 feet to the mile is maintained, however, quite constantly throughout all of this region.

THE RATE OF MOVEMENT.

Determinations showed a rate of movement of the ground waters much greater than had been expected. The first set of underflow stations were established in a north-south line about 2 miles long at a point about 2½ miles west of Garden. The velocities of the ground water at the stations established on this line were found to be remarkably uniform, varying for the most part between 8 and 11 feet per twenty-four hours. The gravel, except occasional layers of silt, was also exceedingly uniform in size and character of grain, a large percentage of the material consisting of grains larger than the size of wheat. The direction of motion at these various stations was in general toward the east, but exceptions were noted from time to time. At the time field work was begun the channel of Arkansas River was dry, as it usually is from June to October. The last summer, however, was exceptional, high floods being of constant occurrence throughout the summer. One of these floods came down the river soon after the first underflow stations were established near the bank of the river, offering an excellent opportunity for determining the influence of the river waters upon the underflow. At one underflow station, situated near the north bank of the channel of the river 2½ miles west of Garden, the direction of the flow of the ground waters was greatly changed by the flood in the river. It was therefore possible to measure the rate at which the river contributed to the ground waters at this point. It was found that the water during the early stages of the flood flowed away from the river at the rate of 8 feet per twenty-four hours. It was not only possible to actually determine this rate of flow by the use of the electric underflow meter, but the northward progress of the water from the river into the gravels could be noted by observation of the changes in the temperature of the ground waters as they flowed northward, the river water being very much warmer. It was also possible to partly trace the inward-moving ground water originating in the river by the change in the chemical composition of the water. Apparatus was at hand for determining the alkalinity, hardness, chlorine, and the total solids dissolved in the water. A further verification of the inward-moving ground water was found in the changed slope of the water plane during the flood periods in the river. The water plane sloped away from the river about 8 feet to the mile during the first stages of high water, corresponding quite accurately with the observed velocities of the water.

Similar determinations were made at a series of stations near Sherlock, 7 miles west of Garden, and at Deerfield, 15 miles west of Garden, and at points near Lakin and Hartland, 21 and 28 miles, respectively, west of Garden. The results differed little from those obtained at the first set of stations, except that more sorting of the gravels had taken place at the points just named, giving greater variety to the rate of movement. The usual velocities varied between 4 and 24 feet per twenty-four hours, the average velocity at 31 underflow stations being 7.9 feet per twenty-four hours. The direction of motion at these various stations corresponded for the most part to the main direction of the river valley, but stations near the sand hills south of the river showed a noticeable northerly component.

VARIATION IN CHEMICAL COMPOSITION OF THE WATER.

Chemical tests of the underflow waters at the various stations showed a marked decrease in the quantity of dissolved solids in the water with the depth penetrated. In sinking test wells at almost any point in the bottom lands of Arkansas River the increasing softness of the water can be noted almost from foot to foot. At a considerable depth, say from 60 to 100 feet or more, there are found waters that are popularly called in this region " second " or " third " waters, which are very much softer than the water obtained from shallow wells; and at the points located in the sand hills south of the river there are places where shallow wells furnish water much softer than the so-called second or third waters found in the vicinity of Garden.

The total solids in the ground water determined at wells in the first camp, 2½ miles west of Garden, varied from 121 parts per 100,000 for water taken 4 feet below the water plane to 103 parts per 100,000 for water taken at 6 feet, and 80 parts per 100,000 for water taken at 14 feet. Water from the railroad well, 130 feet deep, at Garden showed total solids of 16 parts per 100,000. Water in the sand hills south of the river at a depth of 9 feet showed 33 parts per 100,000 total solids, and another well, deeper but of unknown depth, showed 6 parts per 100,000 total solids. The tendency of the ground water near the surface in the bottom lands of the river to run high in dissolved solids seems to indicate that this increased hardness is due to the concentration of the ground water by evaporation. The water plane in these bottom lands lies close to the surface of the ground and is subject to frequent fluctuations, due to changes of conditions in the river itself. These changes are sufficient to account for a large excess of dissolved solids, and it is believed that no other explanation is necessary.

ORIGIN OF THE UNDERFLOW.

The summer's investigation indicates that the water of the Arkansas underflow has its origin in the rainfall upon the sand hills to the south of the river, upon the bottom lands of the valley, and upon the plains north of the river. The average rainfall in the vicinity of Garden is about 20 inches per year. A very large part of this must pass into the open and porous soil, so that the actual contribution to the underflow must be considerable. If the gravels beneath the plains were not so open, so deep, and so wide, the seepage waters would be obliged to seek relief in surface streams, but the underground conditions are such that ample drainage is offered by porous beds of gravel several hundred feet in depth. Even small surface streams, such as Bear Creek and White Woman Creek, are no exceptions to this statement, for these streams entirely disappear as surface streams before the Arkansas is reached, their waters ultimately joining the underflow. In short, the underground drainage in this region is so enormous and the water passes through the gravel so freely that there is no surplus left to form surface streams or a perennial supply for Arkansas River.

Measurement of the elevation of the water in Arkansas River and in certain test wells located at various distances from the north bank of the river for the period from June 16 to July 11, 1904, show that the principal source of ground water in Arkansas Valley at this point is the rainfall. On the night of June 21 a heavy rain raised the water in all of the test wells. The following afternoon, at 3 o'clock, a flood came down the river which raised the water slightly in test well No. 3, 360 feet from the river bank, but the water in wells No. 1 and No. 2 fell during the flood in the river. During the July period the river remained nearly stationary, but several rains raised the level of the ground water in all of the test wells.

The elevation of water in Arkansas River and in test wells located in the bottom lands near Deerfield, Kans., was observed between August 4 and August 14, 1904. Light rains fell on August 4 and August 5, which raised the water in the test wells, but the water in the river fell during the same period. A flood came down the river on August 7, but it did not cause any material change in the elevation of the water in the test walls.

The elevation of water in Arkansas River and in several test wells located near the river, near Sherlock, Kans., was measured between July 15 and August 3, 1904. The water in the test wells was high at the beginning of the period owing to heavy rains preceding July 15. The water in all of the wells fell slowly from July 15 to July 27. A flood began to rise in the river at 11 a. m. on July 27. The flood in the river had an influence on the wells near the river, but well No. 6, 2,500 feet south of the river, continued to fall during the flood period. These observations show that the influence of flood in the river is confined to the strip of land close to the river bank.

NORTH AND SOUTH LIMITATIONS.

A noteworthy feature of the underflow is the lack of any natural north or south limit. The velocities found at the edge of the sand hills south of the river and at a distance as high as 9 miles from the channel of the river are about the same as those found near the bed of the river in similar material. There is nothing surprising in this, except that the stratification of the sand and gravel on the high planes is such as to offer no natural north or south limitation to the eastward-moving ground waters.

STORAGE OF RIVER WATER IN THE UNDERFLOW GRAVELS.

As previously noted, there is one exception that must be made to the statement that the origin of the underflow of the Arkansas is to be found in the rainfall upon the sand hills south of the river and upon the plains to the north of the river. This exception is the contribution of the river itself to the ground waters in times of flood. Actual measurements of this indicate that during flood the Arkansas contributes about 5 second-feet of ground water in each mile of the river channel. This rate was measured during the first stages of flood, and must be a diminishing one, as the flood waters will contribute water more rapidly to the underflow at early than at later stages, on account of the steep gradient that is first established, which necessarily becomes less and less as the flood continues. No measurements of the rate of contribution during the last stages of high water were attempted.

BEAR CREEK.

About 2 miles southeast of Hartland, Kans., is found the dry flood channel of the disappearing plains stream called Bear Creek. This stream is to be classed as a tributary of Arkansas River, although its waters reach the river only at rare intervals, the ordinary flow sinking into the sands at the southern margin of the sand hills on the south side of the river. In time of freshet the waters progress some distance into the sand hills, but ordinarily spread out and sink before they reach the river channel, there being only a few known instances in which a flood in Bear Creek has reached the channel of the Arkansas. An underflow station was established in the dry channel of Bear Creek at a distance of about 1½ miles from the river channel, in order to determine whether any underflow waters could be detected approaching the river from the creek. It was found, however, that the underflow in the dry channel moved in a general easterly direction, following the usual course of the normal Arkansas underflow and passing directly across the course of the creek itself. This observation indicates that any seepage waters entering Arkansas Valley from Bear Creek take up the general eastward movement of the river underflow almost immediately on leaving the sand hills.

RECOVERY OF THE UNDERFLOW.

The principal purpose of the investigations of the underflow of Arkansas River was to determine whether or not it is practicable to recover the ground waters in large amounts for the purpose of irrigation. In order to aid in forming a judgment in this matter careful tests were made upon existing pumping plants in Arkansas Valley in the district under investigation. These pumping plants are confined almost exclusively to the bottom lands of the river, the plants on the uplands being very small affairs, run by windmills and used for irrigating small patches of garden truck and fruit trees. There are several well-constructed wells in the bottom lands of the river, with pumping plants that derive power from gasoline engines. The water plane is so near the surface of the ground and the gravels are so open in texture and contain so little fine material that it is very easy to construct good wells, which furnish a large amount of water for a very small amount of "suction," or lowering of the water level. For this reason the cost of pumping is very low, especially as far as the cost is due to the lift to be overcome by the pumps.

The principal obstacle to successful pumping is the high price of fuel. The current price during 1904 for gasoline in barrel lots was 22 cents a gallon, a price that makes pumping rather expensive for average crops, even under the favorable conditions that exist in the valley. However, there can be no question that the introduction of cheaper fuel, especially the use of producer-gas generators in connection with gasoline engines, will render the recovery of water by pumping plants for irrigation highly profitable in the bottom lands. The discovery of petroleum in Kansas should permit the delivery of crude oil at Garden in large quantities at about 3 cents a gallon, equivalent, if used in attached gas generators, to a 5-cent price for gasoline. At this rate the fuel cost of water should not exceed 75 cents an acre-foot. This prospective low cost makes it doubtful whether it would be practicable to design an infiltration gallery for the recovery of the underflow for use on the bottom lands of the river. The investigations indicate that the most practicable location for the recovery of ground water in large quantities is in the neighborhood of Deerfield, Kans., from which point the waters could be conducted to the head of the Farmers ditch, which has a maximum capacity of about 200 second-feet and at the present time is designed to cover about 8,600 acres of the uplands. The land under the ditch is of very good quality, and the whole problem of its irrigation would be satisfactorily solved, of course, if the perennial flow of Arkansas River could be relied upon. But as the river is dry during the major part of the growing season in an average year, the lands are without irrigation when it is most needed. The entire matter of the practicability of the recovery of ground water for the Farmers ditch depends upon the practicability and cost of an infiltration gallery or of an extensive group of pumping plants. The canals, ditches, and head-gates of the Farmers ditch are worth about $5 per acre for each acre of land covered.

Careful consideration has been given to the matter of the recovery of ground water in Arkansas River Valley by means of gravity. The investigations have shown that the recovery of ground water by means of infiltration galleries or any other form of gravity works is entirely impracticable. The reasons which make this conclusion inevitable may be summarized as follows:

(1) The slope of the water plane in Arkansas Valley is only 7½ feet to the mile, so that, if the conduit be given a slope of 2 feet to the mile, it will have to be 2 miles in length before it has reached a depth of 10 feet below the surface of the ground water. On account of the low gradient of the conduit, its area of cross section will of necessity be very large and the cost of construction will be enormous. The cost will also be increased by the fact that the conduit will have to be constructed for long distances at a considerable depth below the surface of the ground water.

(2) An infiltration gallery, even if constructed, would not furnish an adequate amount of water unless a large number of bored wells were constructed in connection with the gallery and connected to it by pipe lines. This is because stratified gravels do not readity furnish water if the ground water must travel across the direction of the bedding; hence wells must be constructed to penetrate the stratified gravel at right angles to the stratification, in order to secure an adequate amount of water. The wells will cost more than in the case of a pumping plant, because they must be connected to the collecting gallery by pipes which must be put in place at a considerable depth below the water plane.

(3) An infiltration gallery, if constructed, would be undesirable on account of the inelasticity in the amount of water which it would yield. The distance to which the water plane is lowered by the collecting gallery is fixed at the time of construction, and the daily yield of the gallery can not be increased beyond a certain maximum; in fact, at the very time the most water is needed, say in the month of August, the yield of the gallery would be near its minimum. In a pumping plant the vacuum of the pumps can be increased for short periods to correspond with the increased demands for water.

(4) There are no infiltration galleries in actual use for irrigation which have proved to be a success. Many large pumping plants which have turned out to be both practicable and financially successful are used in connection with irrigation work, but the attempts at securing ground water by gravity have nearly always been a disappointment. In some cases a large part of the disappointment has undoubtedly been due to the fact that wells have not been used in connection with the infiltration gallery, so that the ground water was required to flow at right angles to the direction of the stratification of the water-bearing deposits, but this is not sufficient to explain all of the recorded failures.

An underflow ditch was constructed in 1890 in the valley of Arkansas River near Hartland, Kans., about 12 miles west of Deerfield, for the purpose of furnishing water to the Great Eastern canal. The ditch was 7,800 feet long and 20 feet wide at bottom. It was built on a grade of about 3 feet to the mile, and its upper end had reached a depth of about 6 feet below the bed of the river. This ditch was expected to recover ground water under an average head of 3 feet. In the summer following the construction of this ditch the flow was measured by Mr. H. E. Hedge, civil engineer, of Lakin, Kans., by the construction of a weir at its lower end. His field notes show that the discharge at the time of the measurement amounted to 11.63 cubic feet of water per second, or 5,230 gallons per minute. There was a small amount of water in the river at the time the measurements were made. The total area of percolating surface in the underflow ditch was 156,000 square feet. The specific capacity of each square foot of percolating surface under a head of 1 foot amounted to 0.011 gallon per minute. Vertical wells constructed in these same Arkansas gravels show a specific capacity exceeding 0.25 gallon per minute for each square foot of percolating surface under 1 foot head. A comparison of these figures shows the impracticability of collecting water if it must move across the direction of the bedding. These same facts explain the well-known superiority of tubular wells over common, open, dugs wells.

The underflow ditch was not only a failure in the amount of water recovered, but water from the river got into it and partially filled it with sediment. It would have filled up in any case, as, on account of the method of open construction that was used, the gravels would have ultimately worked themselves up by slow movement to the level of the ground water. The discharge from the same underflow canal was measured by Mr. Hedge in the autumn of the same year, when there was no water in the river. The discharge had fallen at this time to 65 cubic feet per second.

An underflow ditch, constructed at great expense near Dodge, Kans., on even a larger scale, has practically the same history as the one reported above.

The Denver Union Water Company put an underflow water gallery in Cherry Creek at an expenditure of $200,000, and succeeded in developing only 5 cubic feet of water per second.

The Colorado Fuel and Iron Company placed a concrete dam across the St. Charles at a cost of $10,000, and developed 1½ cubic feet of water per second. This shows that the enormous first cost renders the gravity method prohibitive.

An infiltration canal was constructed at great expense near Sacaton, Ariz., on the Gila Indian Reservation. It was a complete failure.

A gravity infiltration canal constructed on Cimarron River, near Englewood, Kans., consisted of 900 feet of stave pipe and 2,000 feet of open cut. A flood in the river filled the canal with sand and mud and washed out a large part of the stave pipe immediately after its completion.

As an alternative scheme, a system of pumping plants is being designed to recover the underflow water near Deerfield and conduct the water into the Farmers ditch. The first cost of such a plant will undoubtedly be much less than that of an infiltration gallery.

RESULTS OF TESTS OF SMALL PUMPING PLANTS IN THE ARKANSAS VALLEY.

The accompanying table shows the results of tests of a number of pumping plants used for irrigation, situated in Arkansas Valley between Garden and Lakin, Kans. Most of the entries in the table explain themselves.

The fuel used in all of the plants is gasoline. The current price of gasoline during the summer of 1904 was 22 cents a gallon, which is almost prohibitive even when used for pumping water from the most excellent wells found in this valley.

Table of data from tests of small pumping plants, Arkansas Valley, Kansas.

1.	2.	3.	4.	5.	6.	7.
Owner of plant.	Location.	Kind of pump.	Horse-power of engine.	Fuel used.	Price of fuel.	Total lift.
					Per gal.	*Feet.*
D. H. Logan	Garden, Kans	No. 3 centrifugal	6	Gasoline	$0.22	22.1
Mrs. M. Richter	do	Menge	10	do	.22	15.5
C. E. Sexton	do	2 vertical 6 by 6 cylinder.	1½	do	.22	15.06
Fulmer	Lakin, Kans	Chain and bucket.	7	do	.21	17.0
Root	do	do	2½	do	.22	15.82

	8.	9.	10.	11.	12.	13.	14.
Owner of plant.	Distance water is lowered.	Yield of well.	Specific capacity of well.	Area of percolating or strainer surface.	Specific capacity per square foot of strainer.	Cost of fuel per acre-foot of water.	Cost of fuel per 1,000 foot-gallons.
	Feet.	*Gallons per minute.*	*Gallons per minute.*	*Square feet.*	*Gals. per minute.*		*Cents.*
D. H. Logan	6.85	272	42.2	107.0	0.394	$2.93	1/25
Mrs. M. Richter	5.1	394	90.4	266.5	.341	2.90	1/17
C. E. Sexton	3.0	91	30.3	57.2	.53	3.75	1/13
Fulmer	6.35	540	97.0	336.4	.254	1.37	1/40
Root	4.16	215	51.7	206.9	.246	2.78	1/18

SPECIFIC CAPACITY.

The numbers in column 10 express the readiness with which the wells furnish water to the pump. The numbers in each case were found by dividing the numbers in column 9 by the corresponding numbers in column 8; these numbers, therefore, express the amount of water the well would furnish if the water level was lowered but

1 foot. These numbers constitute what the writer has called the "specific capacity" of the well, and are large in the case of a good well and small in case of a poor one.

In few places in the country are better wells constructed than in the vicinity of Garden and in the area lying west of that place, in the Arkansas Valley. The water-bearing gravels are usually only from 9 to 15 feet below the surface, and good wells can be very cheaply constructed. There is no quicksand or hardpan or other troublesome material above the water-bearing gravels. The well tubes or strainers are usually 10 to 20 inches in diameter, and are made of slotted galvanized iron. For the most part the wells in Arkansas Valley are of the very best design, and possess a remarkably high specific capacity, as the table shows. The well usually constructed is a dug well 6 to 10 feet in diameter, excavated several feet below the level of ground water, with a number of "feeders" or tubular wells penetrating the bottom of the well. No better form of construction can be suggested for this locality. The only modification in detail that seems likely to better the present excellent results would be the use of galvanized-iron strainers with larger slots than are at present in use. This would certainly be practicable at some of the wells. In these cases heavy pumping would remove much of the fine material that now remains in permanent contact with the present well strainers.

In column 12 are given the same magnitudes that are expressed in column 10, reduced in each case to 1 square foot of well strainer. The numbers in this column represent, therefore, the amount of water in gallons per minute furnished by 1 square foot of well strainer under a head of 1 foot of water. They are numerical expressions of the degree of coarseness of the material in which the well is placed.

These numbers are almost the same for all of the wells when proper allowance is made for difference in construction. At the Richter, Fulmer, and Root plants there are large dug wells, with several feeders in the bottom, and the numerous feeders interfere with one another somewhat, keeping the specific capacity lower than it otherwise would be. At the Logan and Sexton plants the method of construction is different. The Logan well has 20-inch casing, through the bottom of which pass two 4-inch feeders, extending 26 feet lower. The 20-inch casing is perforated for 10 feet at the bottom. At the Sexton plant there is a 12-inch well 22 feet deep and a 10-inch well 31 feet deep, both perforated 10 feet from the bottom.

COST OF PUMPING.

The cost of pumping in the bottom lands is very low, as far as the expense is due to the distance that the pumps must lift the water. The cost of pumping can not be materially lowered by any changes in the method of well construction. The most practicable modification would seem to be in the use of producer gas in connection with gasoline engines. It ought to be possible to make use of Colorado coke or anthracite coal in small producer plants and to procure water at a fuel cost of 75 cents per acre-foot. For this purpose the engines should be in units of 15 to 50 horsepower, with wells of sizes to correspond.

That part of the operating expense which is properly chargeable to fuel cost can be accurately determined. Column 13 expresses the cost per acre-foot of water recovered. In column 14 there is given the cost of fuel for lifting 1,000 gallons of water through a distance of 1 foot. For the purpose of comparison these results are expressed in fractional parts of a cent. It should be noted that the cost given in the table is based upon a 22-cent price for gasoline. There is no doubt that the use of producer-gas plants in moderate-sized units would make irrigation by pumping on the bottom lands of Arkansas River highly profitable.

In the estimates of cost of water no allowance has been made for interest, depreciation, and labor. These expenses, if included, would about double the tabulated cost per acre-foot.

HOLCOMB WELL.

A very important attempt to recover water from the underflow has been made during the present season by the owners of the Riverside stock ranch, located about 7 miles west of Garden. A well 200 feet long and 5 feet wide, excavated to a depth of 9 or 10 feet below the water plane, has been constructed of sheet piling. Three galvanized-iron 16-inch feeders have been sunk in the bottom of this well to a depth of about 20 feet. A 75-horsepower Corliss engine with condenser, a 90-horsepower boiler, and a No. 14 Byron Jackson centrifugal pump have been put in position at the north end of the well. Foundations for the engine and pump and buildings to cover the machinery have been constructed in the very best manner. The pumping plant is now just ready to be put in operation. A preliminary test with three feeders in place showed a capacity of 2,500 gallons per minute. As soon as the engine and pump are in satisfactory working order it is proposed to sink a large number of additional feeders in the expectation of increasing the capacity to 6,000 gallons per minute. The approximate cost of the plant is about $8,000 for machinery and $4,000 for the well. The owners expect to use Trinidad slack coal for fuel, at a cost of $4 to $4.50 per ton. A complete test of this pumping plant will be made and the report published as soon as the material is available.

OPERATIONS IN MONTANA.

By Cyrus C. Babb.

MILK RIVER PROJECT.

The location and extent of the Milk River project was described in the First Annual Report of the Reclamation Service, pages 203 to 214, and in the Second Annual Report, pages 332 to 350. Field work was continued during 1904, this being the fifth year of surveys since the first examination and reconnaissance in 1900. The general scheme is divided into two parts: First, storage of the flood waters of St. Mary River and their diversion into the headwaters of Milk River; and, second, the utilization of this water on the irrigable lands of lower Milk River Valley in Montana.

The investigation has brought out three methods of utilizing the water of St. Mary basin: (1) By diverting St. Mary River to North Fork of Milk River, and allowing it to run through Canada to lower Milk River Valley in Montana; (2) by utilizing the waters on the eastern section of the Blackfeet Indian Reservation and on the lands immediately adjacent to the east; (3) by carrying the water from the head of St. Mary River across both the North Fork and South Fork of Milk River to Cutbank Creek, allowing it to flow down this and Marias River, 100 miles or more, then taking it out of the Marias by a canal to Big Sandy Creek, a tributary of Milk River.

The most feasible project is the one first mentioned, but there are a number of international questions connected with it that are likely to cause complications.

The first difficulty arises from the fact that there is already a canal in Canadian territory diverting water from St. Mary River. This canal is located about 7 miles north of the international line, and is owned by the Canadian Northwest Irrigation Company, the total length of whose system is 200 miles, including laterals. The capacity of the canal, as originally designed, is 382 second-feet, but it is doubtful if the present construction can carry more than one-half of this quantity.

The second difficulty is that after St. Mary River has been turned into Milk River water may be taken from the latter stream in Canada. Such a diversion is possible, and there is now being constructed a canal diverting water from the north side of Milk River in Canada, about 12 miles below the junction of North and South forks. The computed discharge is 330 second-feet. The general course of the canal follows the line of the Alberta Railroad Company. The water is to supplement the irrigation system from St. Mary River above described, and will irrigate lands in the vicinity of Lethbridge, Alberta, Canada.

To thoroughly settle the question of water diversion from St. Mary River and Milk River it will probably be necessary to come to some international agreement with Canada. This country has the advantage of storage in St. Mary Lakes by the construction of the St. Mary dam, in which the flood waters of this stream can be conserved and afterwards used for irrigation purposes. An agreement might be made with the Canadian government to allow to pass down without diversion the water turned into Milk River, on condition that the Canadian canal from St. Mary River will be furnished sufficient water from the St. Mary reservoir.

IRRIGABLE AREA.

The Milk River project, as designed, contemplates reclaiming 270,000 acres, divided into two sections, viz, 111,500 acres by diversions near Chinook and 159,000 acres, extending eastward as far as Glasgow, from the Dodson diversion dam. The Marias subproject, which has been considered as a connecting link between the St. Mary basin and the lower Milk River Valley, can irrigate 200,000 more acres of land, all located in one tract between lower Marias River and Big Sandy Creek, and extending northward across the Great Northern Railway. Pl. XXVIII is a map of the proposed Milk River project and canal system.

ST. MARY BASIN.

During the first three years of the investigation attention was chiefly given to surveys in the St. Mary basin, where it is proposed to store flood waters of a portion of the Rocky Mountain slope. Complete surveys and borings have been made at the dam site and a canal location has been projected, extending from the lakes to the North Fork of Milk River. By means of a canal 27.4 miles long, and with no especial engineering difficulties, the stored waters of St. Mary River may be conducted to the head of Milk River. For a thorough discussion of the results of work in this section reference should be made to the two preceding annual reports. No field work has been carried on in this section during the current year. Final plans and designs for the controlling works at St. Mary dam were made during the winter of 1903 and 1904.

MARIAS SUBPROJECT.

During 1902 parties were investigating the possibilities of storage in the upper basin of the Marias, while other parties were making surveys along the lower stretches of this stream in order to find a point where a possible diversion could be made for a canal to Big Sandy Creek.

On the upper river the most feasible reservoir site was found to be that of Two Medicine Lake. The following table shows capacities for different heights of dam:

Capacities of Two Medicine Lake reservoir, Montana.

Contour.	Area.	Capacity of sections.	Total capacity.	Top length of dam.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*	*Feet.*
4,850	1.5	0	0	....
4,854	352.5	708	708	65
4,860	538.4	2,673	3,381	172
4,870	722.7	6,305	9,686	453
4,880	854.0	7,884	17,570	700
4,890	1,004.5	9,293	26,863	960
4,900	1,100.8	10,527	37,390	1,225
4,910	1,187.3	11,441	48,831	1,505
4,920	1,260.3	12,238	61,069	1,640
4,930	1,330.2	12,952	74,021	1,940
4,940	1,393.1	13,617	87,638	2,150

The work on the lower Marias during 1902 consisted in mapping the canyon on a scale of one-fifth mile to the inch, with contour intervals of 20 feet, the section mapped extending from the crossing of the Great Falls and Canada Railway to below the mouth of Cottonwood Creek. Early in the season of 1904 this work was continued by making a reconnaissance map, on a scale of 2,000 feet to 1 inch, of the river canyon from Cottonwood Creek to below the mouth of Black Coulee. The results of this reconnaissance showed that the best location for a dam was almost exactly along the range line between ranges 7 and 8 east.

In August detailed surveys were begun, consisting in mapping the dam site and the canyon itself from the dam site to the divide between the Marias River drainage and Big Sandy Creek, all on a scale of 100 feet to 1 inch, with 5-foot contours.

Diamond-drill borings were also taken across the line of the dam, the located spillway, and the projected tunnel line. The following table shows the results of these borings:

Borings at Marias River dam site, Montana, 1904.

Hole No.	Distance from left abutment.	Depth to rock.	Total depth.	Surface elevation.	Bottom elevation.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*
A 1	....	16	40	2,682.2	2,642
A 2	....	10	46	2,681.2	2,635
B 1	....	7	22	2,679.7	2,658
B 2	....	27	56	2,694.7	2,639
C 1	1,030	15	71	2,697.0	2,626
C 2	1,140	16	22	2,698.5	2,678
C 3	1,265	8	33	2,728.7	2,696
C 4	1,370	4	49	2,731.8	2,683
C 5	1,490	2	53	2,735.4	2,682
C 6	1,560	4	21	2,739.1	2,718
C 7	810	7	20	2,685.0	2,665
C 8	715	11	21	2,685.9	2,665
C 9	630	9	56	2,686.7	2,631
C 10	530	11	66	2,692.8	2,627
C 11	371	12	15	2,698.8	2,684
C 12	380	7	48	2,753.5	2,707
C 13	1,870	33	71	2,799.2	2,728
C 14	1,970	35	39	2,804.3	2,765
C 15	2,070	40	42	2,808.8	2,766
C 27	1,424	3	70	2,734.0	2,664
C 28	1,315	3	45	2,730.1	2,685
C 29	988	5	32	2,684.2	2,652
C 30	911	[a] 6	80	2,684.0	2,604
C 31	765	11	80	2,685.7	2,606

[a] 2 feet of water.

Borings at Marias spillway.

Hole No.	Distance from hole No. 19.	Depth to rock.	Total depth.	Surface elevation.	Bottom elevation.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*
C 16	308	25	109	2,770.3	2,661
C 17	233	24	36	2,810.4	2,774
C 18	75	38	51	2,918.3	2,867
C 19	0	59	102	2,947.0	2,845
C 20	102	51	100	2,948.7	2,849
C 21	202	52	100	2,948.4	2,848
C 22	95	53	100	2,950.3	2,850
C 23	200	50	100	2,951.2	2,851
C 24	400	12	100	2,887.8	2,788
C 25	175	9	100	2,860.0	2,760
C 26	188	18	75	2,880.9	2,806

Borings at Marias tunnel line.

Hole No.	Distance from hole to hole.	Depth to rock.	Total depth.	Surface elevation.	Bottom elevation.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*
D 1	0	4	61	2,744.3	2,683
D 2	102	1	47	2,726.4	2,679
D 3	98	1	46	2,725.4	2,679
D 4	101	0	41	2,720.9	2,680
C 4	110	4	49	2,731.8	2,683
D 5	98	3	68	2,747.2	2,679
D 6	108	4	61	2,741.3	2,680
D 7	102	7	57	2,737.0	2,680
D 8	97	7	51	2,730.6	2,680
D 9	111	8	30	2,725.8	2,696
D 10	54	8	44	2,723.3	2,679

Lines A and B are about 1 mile below the main location of the dam. Line C, holes 1 to 15, inclusive, and 27 to 31, inclusive, is along the main axis of the dam. Holes 16 to 26 are at the spillway location; 19 to 23 being along the crest; 16, 17, 18, 24 transverse to the crest, and 25 and 26 on the downstream side of the spillway, near the right and left hand edges of it, respectively. Line D, holes 1 to 10, is along line of projected outlet tunnel.

Hole 1 A: 0 to 4 feet, sand; 4 to 11 feet, sand, gravel, and small bowlders; 11 to 16 feet, sand, streaks of gravel; 16 to 20 feet, tough sandy clay; 20 to 39.5 feet, tough, sandy clay. At 39.5 feet, struck hard rock.

Hole 2 A: 0 to 1 foot, sand; 1 to 6 feet, sand, gravel, and small bowlders; 6 to 10.5 feet, sand, gravel, and small bowlders; 10.5 to 18 feet, fairly hard gray sandstone; 18 to 21 feet, fairly hard yellow sandstone, will not hold water; 21 to 46 feet, fairly hard gray sandstone, a little clay in it.

Hole 1 B: 0 to 7 feet, sand, gravel, small bowlders, water runs away; 7 to 10 feet, fairly hard gray sandstone; 10 to 21.5 feet, sandstone, a little softer, will not hold water; at 21.5 feet, struck hard rock. Put casing down by blasting from 10 to 22 feet. Made 6 inches in rock at bottom with 7 shots.

Hole 2 B: 0 to 14 feet, compact sand and sandy clay; 14 to 17 feet, sand; 17 to 27 feet, sand, small bowlders, and gravel; 27 to 29 feet, hard rock, probably loose; 29 to 45 feet, rather soft gray sandstone with clay in it; 45 to 56 feet 4 inches, struck hard rock.

Hole 1 C: 0 to 1 foot, soil; 1 foot to 7 feet, compact sand and a little clay; 7 to 15 feet, sand, gravel, and small bowlders; 15 to 30 feet, rather soft sandstone with a little clay in it; 30 to 34 feet, rather soft sandstone with a little clay in it; 34 to 59 feet, very tough blue clay with a little sand in it; 59 to 70 feet 9 inches, harder clay. At 70 feet 9 inches, hard rock.

Hole C 2: 0 to 9 feet, sand; 9 to 14 feet, soft sandy clay; 14 to 16 feet, sand; 16 to 20 feet 4 inches, fairly hard sandstone; a little clay. At 20 feet 4 inches, struck hard rock.

Hole C 3: 0 to 8 feet, sand; 8 to 10.5 feet, hard sandstone; 10.5 to 30.5 feet, hard sandstone; 30.5 to 33 feet, hard sandstone.

Hole C 4: 0 to 4 feet, sand; 4 to 14 feet, rather soft sandstone; 14 to 16 feet, hard sandstone; 16 to 49.5 feet, fairly hard sandstone; at 49.5 feet, very hard rock.

Hole C 5: 0 to 2 feet, sand; 2 to 20 feet, rather soft sandstone; 20 to 22.5 feet, fairly hard sandstone; 22.5 to 24.5 feet, hard sandstone; 24.5 to 32 feet, rather soft sandstone; 32 to 53 feet, fairly hard sandstone; at 53 feet, very hard rock.

Hole C 6: 0 to 4 feet, sand; 4 to 20 feet, fairly hard sandstone; 20 to 21.5 feet, hard sandstone.

Hole C 7: 0 to 7 feet, sand; 7 to 20 feet, fairly hard sandstone; 20 to 20.5 feet, hard sandstone.

Hole C 8: 0 to 11 feet, sand, gravel, small bowlders; 11 to 20 feet, fairly hard sandstone; 20 to 20.5 feet, hard sandstone.

Hole C 9: 0 to 9 feet, sand, gravel, small bowlders; 9 to 56 feet, fairly hard sandstone, some clay in it; at 56 feet, very hard rock.

Hole C 10: 0 to 2 feet, sand; 2 to 4 feet, loose rock; 4 to 8 feet, sand, clay, and rotten wood; 8 to 11 feet, sand, gravel, and small bowlders; 11 to 19.5 feet, rather soft sandstone, with considerable clay in it; 19.5 to 20 feet, hard sandstone; 20 feet to 57 feet 9 inches, fairly hard sandstone, with some clay in it, hardening and running into clay at 57 feet; 57 feet 9 inches to 59 feet, hard slate; 59 to 65 feet, layers of hard clay and slate.

Hole C 11: 0 to 5 feet, compact sand; 5 to 12 feet, compact sandy clay; 12 to 15 feet, fairly hard gray sandstone; at 15 feet, very hard.

Hole C 12: 0 to 7 feet, compact sandy clay; 7 to 10 feet, hard sandstone; 10 to 19 feet, fairly hard sandstone; 19 to 21 feet, soft sandstone; 21 to 47 feet, fairly hard sandstone; 47 to 48 feet, hard sandstone.

Hole C 13: 0 to 13 feet, compact sand; 13 to 16 feet, sandy clay; 16 to 33 feet, compact sand; 33 to 70 feet, fairly hard sandstone; 70 to 71 feet, hard sandstone.

Hole C 14: 0 to 14 feet, compact sand; 14 to 35 feet, compact sand, with considerable clay in it; 35 to 38 feet, fairly hard sandstone; 38 to 39 feet, hard sandstone.

Hole C 15: 0 to 11 feet, compact sand, occasional loose rock; 11 to 35 feet, clay, with some sand in it; 35 to 36 feet, fairly hard coarse sandstone; 36 to 40 feet, tough sandy clay; 40 to 42 feet, tough sandy clay; 42 to 42.5 feet, hard sandstone.

Hole C 16: 0 to 5 feet, sandy clay; 5 to 7 feet, sand, gravel, and small bowlders; 7 to 14 feet, rather soft sandstone; 14 to 51 feet, fairly hard sandstone; 51 to 79 feet, harder sandstone, occasional soft streaks; 79 to 90 feet, fairly hard gray sandstone; 90 to 99 feet, very hard clay, a little sand in it; 99 to 108 feet, tough sandy clay; 108 to 108.5 feet, hard sandstone.

Hole C 17: 0 to 14 feet, sandy clay, loose pieces sandstone; 14 to 24 feet, compact clay, streaks of sand; 24 to 35 feet, fairly hard sandstone; 35 to 36 feet, hard sandstone.

Hole C 18: 0 to 6 feet, sandy clay; 6 to 9 feet sand and gravel; 9 to 18 feet, streaks of sandy clay and soft slate; 18 to 30 feet, very tough blue clay and soft slate; 30 to 38 feet, very tough blue clay, streaks of soft shale; 38 to 50 feet, fairly hard sandstone, streaks hard clay; 50 to 51 feet, hard sandstone.

Hole C 19: 0 to 7 feet, sandy clay, gravel, and small bowlders; 7 to 18 feet, layers of sand and sandy clay; 18 to 32 feet, clay, occasional streaks of soft shale; 33 to 59 feet, tough clay, streaks of soft shale; 59 to 102 feet, fairly hard sandstone, streaks of tough clay; 102 to 102.5 feet, hard gray sandstone.

Hole C 20: 0 to 8 feet, sandy clay, small bowlders, and gravel; 8 to 47 feet, mainly clay, occasional streaks of soft shale; 47 to 51 feet, layers clay and soft shale; 51 to 72 feet, fairly hard sandstone, streaks tough clay; 72 to 73.5 feet, hard gray sandstone; 73.5 to 74 feet, hard sandstone; 74 to 97 feet, fairly hard sandstone, streaks of shale; 97 to 100 feet, hard sandstone.

Hole C 21: 0 to 13 feet, sandy clay, gravel, and small bowlders; 13 to 52 feet, layers of clay and soft shale; 52 to 81 feet, fairly hard sandstone, streaks of very tough clay; 81 to 83 feet, hard sandstone; 83 to 86.5 feet, fairly hard sandstone, streaks of very tough clay; 86.5 to 87.5 feet, hard slate; 87.5 to 96 feet 7 inches, fairly hard crumbly shale; 96 feet 7 inches to 97 feet, hard slate; 97 to 100 feet, very tough, slaty clay.

Hole C 22: 0 to 9 feet, sandy clay and small bowlders; 9 to 24 feet, layers of sand and tough, sandy clay; 24 to 52 feet, tough clay, occasional streaks of soft shale; 52 to 66 feet, fairly hard sandstone, streaks of tough clay; 66 to 66.5 feet, hard sandstone; 66.5 to 77 feet, fairly hard sandstone, streaks of tough clay; 77 to 77.5 feet, hard sandstone; 77.5 to 86 feet, fairly hard sandstone, streaks tough clay; 86 to 87 feet 9 inches, hard sandstone; 87 feet 9 inches to 100 feet, as 77.5 to 86 feet.

Hole C 23: 0 to 9 feet, sandy clay, gravel, and small bowlders; 9 to 35 feet, tough clay, streaks of soft shale; 35 to 50 feet, clay with layers of sand and shale; 50 to 72 feet, fairly hard sandstone with streaks of clay; 72 to 72.5 feet, hard sandstone; 72.5 to 80 feet, fairly hard sandstone, streaks of tough clay; 80 to 84 feet, hard sandstone; 84 to 100 feet, fairly hard sandstone, streaks of very tough clay.

Hole C 24: 0 to 6 feet, sand, gravel, and bowlders; 6 to 9.5 feet, very tough clay; 9.5 to 11.5 feet, hard sandstone; 11.5 to 63.5 feet, fairly hard sandstone and streaks of very tough clay; 63.5 to 65 feet, hard sandstone; 65 to 87 feet, fairly hard sandstone and streaks of very tough clay; 87 to 87.5 feet, hard sandstone; 87.5 to 92 feet, fairly hard sandstone; 92 to 100 feet, fairly hard sandstone.

Hole C 25: 0 to 9 feet, tough clay and soft shale; 9 to 91 feet, fairly hard sandstone and very tough clay, 91 to 92 feet, hard sandstone; 92 to 100 feet, fairly hard sandstone and very tough clay.

Hole C 26: 0 to 9 feet, sand and sandy clay; 9 to 17.5 feet, fairly hard sandstone and very tough clay; 17.5 to 18 feet, hard sandstone; 18 to 65 feet, fairly hard sandstone and streaks of very tough clay; 65 to 65.5 feet, hard sandstone; 65.5 to 75 feet, fairly hard sandstone and streaks of very tough clay.

Hole C 27: 0 to 3 feet, sand; 3 to 15 feet, rather soft sandstone; 15 to 17 feet, fairly hard sandstone; 17 to 19 feet, hard sandstone; 19 to 38 feet 7 inches, fairly hard sandstone; 38 feet 7 inches to 39 feet 7 inches, hard sandstone; 39 feet 7 inches to 44.5 feet, fairly hard sandstone; 44.5 to 45 feet, hard sandstone; 45 to 51 feet, fairly hard sandstone; 51 to 52 feet, hard sandstone; 52 to 68.5 feet, fairly hard sandstone; 68.5 to 69 feet, hard sandstone; 69 to 70 feet, fairly hard sandstone.

Hole C 28: 0 to 3 feet, sand; 3 to 11.5 feet, fairly hard sandstone; 11.5 to 12.5 feet, hard sandstone; 12.5 to 32 feet 8 inches, fairly hard sandstone; 32 feet 8 inches to 33 feet, hard sandstone; 33 to 45 feet, fairly hard sandstone.

Hole C 29: 0 to 5 feet, sand, gravel, and bowlders; 5 to 32 feet, fairly hard sandstone.

Hole 5 D: 0 to 3 feet, sand; 3 to 7 feet, rather soft sandstone; 7 to 13.5 feet, fairly hard sandstone; 13.5 to 14.5 feet, hard sandstone; 14.5 to 24 feet, rather soft sandstone; 24 to 35.5 feet, fairly hard sandstone; 35.5 to 36 feet, hard sandstone; 36 to 68 feet, fairly hard sandstone.

Hole 6 D: 0 to 4 feet, sand; 4 to 9 feet, fairly hard sandstone; 9 to 10 feet, hard sandstone; 10 to 17 feet, rather soft sandstone; 17 to 38 feet, fairly hard sandstone; 38 to 41 feet, hard sandstone; 41 to 61 feet, fairly hard sandstone.

Hole 7 D: 0 to 7 feet, sand; 7 to 12 feet, rather soft sandstone; 12 to 57 feet, fairly hard sandstone.

Hole 8 D: 0 to 7 feet, sand; 7 to 13 feet, rather soft sandstone; 13 to 51 feet, fairly hard sandstone.

Hole 9 D: 0 to 8 feet, sand; 8 to 13 feet, rather soft sandstone; 13 to 30 feet, fairly hard sandstone.

Hole 10 D: 0 to 8 feet, sand; 8 to 14 feet, rather soft sandstone; 14 to 44 feet, fairly hard sandstone.

Hole 4 D: 0 to 19 feet, fairly hard sandstone; 19 to 20 feet, hard sandstone; 20 to 29.5 feet, fairly hard sandstone; 29.5 to 32 feet, hard sandstone; 32 to 41 feet, fairly hard sandstone.

Hole 3 D: 0 to 1 foot, sand; 1 to 4 feet, hard sandstone; 4 to 18 feet, fairly hard sandstone; 18 to 18.5 feet, hard sandstone; 18.5 to 33 feet, fairly hard sandstone; 33 to 46 feet, fairly hard sandstone.

Hole 2 D: 0 to 1 foot, sand; 1 to 26 feet, fairly hard sandstone; 26 to 29 feet, hard sandstone; 29 to 47 feet, fairly hard sandstone.

Hole 1 D: 0 to 4 feet, sand; 4 to 30 feet, rather soft sandstone; 30 to 61 feet, fairly hard sandstone.

Hole C 31: 0 to 11 feet, sand; 11 to 15 feet, rather soft sandstone with some clay in it; 15 to 30 feet, fairly hard sandstone; 30 to 50 feet, tough blue clay; 50 to 59 feet, streaks of clay, fairly hard, and hard sandstone; 59 to 63 feet, hard sandstone; 63 to 80 feet, streaks of clay and sandstone.

Hole C 30: 0 to 2 feet, water; 2 to 6 feet, sand, gravel, and bowlders; 6 to 16 feet, fairly hard sandstone; 16 to 36 feet, tough, sandy clay; 36 to 57 feet, fairly hard sandstone, very tough clay, and thin streaks of hard sandstone; 57 to 80 feet, fairly hard sandstone, very tough, sandy clay, and streaks of hard sandstone less than 1 inch thick.

As at present contemplated, an earthen dam from 150 to 195 feet in height is to be constructed. Good sand rock for the foundation of the core wall was found at a reasonable depth.

From the dam a canal 17.4 miles long will conduct the water through the divide to the Big Sandy Creek drainage. Only about 7 miles will be of difficult canyon construction and the formation through this stretch is favorable for a safe location, as it is composed largely of horizontal sandstone strata, not liable to slide when water is placed in the canal.

About 10 miles beyond the end of the canal, and about 27 miles below the dam, occurs a natural reservoir site, known as Lonesome Lake, which has been mapped this season. By the construction of a comparatively short dam in the narrow outlet of the lake water to the desired quantity can be stored. The following table shows the capacity of the lake for different heights of dam:

Capacities of Lonesome Lake reservoir at different contours.

Contour.	Area.	Capacity between contours.	Total capacity.
Feet.	*Acres.*	*Acre feet.*	*Acre feet.*
2,650	1,135	....	....
2,660	4,616	28,755	28,755
2,670	8,977	67,965	96,720
2,680	13,339	111,580	208,300

TOPOGRAPHIC SURVEYS.

During the current year there have been mapped, under the direction of the topographic branch, 3 quadrangles, known as Lonesome Prairie, Box Elder, and Kremlin quadrangles, together with portions of two other quadrangles, which will cover all agricultural land that can be irrigated by the projected canal.

IRRIGABLE LANDS.

By means of the topographic maps of the general canal and lateral systems and of the land that can be irrigated the extent of irrigable land has been determined to be about 200,000 acres.

The Marias surveys were begun to ascertain whether that stream could act as the connecting link between St. Mary basin and lower Milk River Valley. It is believed, however, that they have disclosed a good project—that of utilizing the waters of Marias River alone on the adjacent lands lying between the lower Marias and Big Sandy Creek and extending northward beyond the Great Northern Railway.

If negotiations can be consummated with Canada for conducting the St. Mary water through Milk River in Canada, the Marias may be abandoned as a link and considered on its proper merits alone.

RESERVOIR WITHDRAWALS.

In connection with the Marias subproject two separate reservoir withdrawals have been made: First, on July 21, 1904, of the canyon of Marias River, or lands that will be flooded by the construction of the Marias dam, and, second, on October 8, 1904, of the Lonesome Lake reservoir.

LOWER MILK RIVER.

CHAIN LAKES RESERVOIR.

The work of the topographic division this year showed that there is a reservoir site on Milk River, 30 miles northwest of Havre, at what is known as Chain Lakes. This is a coulee about 10 miles long, running parallel to the river 2 or 3 miles west of it, and draining into Milk River at both its upper and lower ends.

The first idea was to dam the lower end of the coulee and then bring water into it by a feed canal from Milk River. The average elevation of the bottom of the coulee is 2,600 feet, and it was contemplated storing to the 2,660-foot contour, which would give a capacity of 104,000 acre-feet. Reconnaissance of Milk River above showed that a feed canal was impracticable, as the canal would have to be 20 miles long and extend along the top of the Milk River bluffs for nearly its entire distance. These bluffs are steep, nearly perpendicular in places, and very rocky. The cost of construction would be high and the maintenance very difficult.

The idea was then developed of building a dam across Milk River itself a short distance below the upper end of the coulee leading into Chain Lakes, and then damming the lower end of the lakes themselves. This latter point may also be used as the main spillway. The dam site on Milk River is located at the Watson ranch, where the elevation of the bed of the river is 2,547 feet. It is proposed to store water to 2,630 feet, which will bring the upper end of the reservoir within 7 miles of the International Boundary line. The length of a dam at the 2,630-foot level would be 2,210 feet. The following table shows the capacity of the reservoir to the different contours:

Capacities of Chain Lakes reservoir at different contours.

Contour.	Area.	Capacity between contours.	Total capacity.	Length of dam.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*	*Feet.*
2,560	569	....	....	1,820
2,570	1,454	10,110	10,110	1,970
2,580	3,271	23,620	33,730	2,020
2,590	5,174	42,220	75,950	2,060
2,600	6,834	60,040	135,990	2,110
2,610	9,139	79,860	215,850	2,140
2,620	10,891	100,150	316,000	2,170
2,630	13,422	121,560	437,560	2,210
2,640	15,971	146,960	584,520	2,250
2.650	18,359	171,650	756,170	2,280

If this scheme proves feasible, the Chain Lakes reservoir will take the place of the Bowdoin reservoir, and will therefore dispense with an expensive feed canal, changes in the tracks of the Great Northern Railway, and the settlement of the private claims on Lake Bowdoin.

It also has the advantage of being located above all the irrigable lands of Milk River Valley. If the Marias diversion should be completed, a canal leading from this stream would be well above the Chain Lakes reservoir and could conduct waters to it.

There are a number of small private systems of canals out of Milk River, near Chinook. The Chain Lakes reservoir will be above here, and it will, therefore, be necessary to adjudicate these vested rights before construction is started.

The private-land rights affected by the Chain Lakes reservoir, or lands that will be flooded by the reservoir, amount to only 2,640 acres, consisting mainly of small detached sheep ranches.

In connection with this project certain lands have been withdrawn for reservoir purposes, as requested in letters to the Secretary of the Interior dated August 3, 1904, and October 8, 1904.

CHINOOK DIVERSIONS.

During 1903 a survey was made for a canal on the north side of Milk River, heading near Yantic, 10 miles above Chinook, and extending eastward as far as Coburg. The total length of this would be 54 miles, and the area covered 63,490 acres. Of this probably 80 per cent is in private ownership. The canal is located at the base of the foothills, and covers all the available land on the north side of the river.

During 1904 a canal has been surveyed from the south side of Milk River, heading about 3 miles southeast of Chinook. It continues eastward through the Fort Belknap Indian Reservation, and will be 57 miles long. It has a most excellent location, with very little sidehill construction and only a few flume crossings. The total area covered is 48,000 acres, of which 15,000 acres are west of the reservation and the balance on the reservation itself. In order to make this latter area available the opening of a portion of the Indian reservation would be necessary. Of the acreage west of the reservation a very large proportion is in private ownership, and probably 60 per cent of it is served by private canals. This latter service is not as efficient as that on the north side, and it is believed, after conversation with a number of owners on the south side, that they would be willing to abandon their water rights and ditches in favor of the Government.

DODSON DIVERSION.

The first plan contemplated here was the building of a diversion weir in Milk River 3 miles above Dodson, to conduct the flood waters of the river in a canal 30 miles long, on the south side, to Bowdoin Lake. The stored water in this reservoir was to be distributed to lands as far to the east as Glasgow. A detailed description is given in the Second Annual Report, pages 346 to 350.

Borings were continued and completed in July, 1904, at the Dodson dam site. During the previous year holes were drilled mainly in the bed of the river, and included holes Nos. 1 to 11, inclusive. The remainder of the drilling was on the hill immediately south of the river, where it is proposed to construct the spillway. The material encountered down to rock was gravel, sand, and loose bowlders. A few test holes were also placed on the line of the Malta south canal, where it passes through what is known as "Rocky Point," about 7 miles below the Dodson dam.

The following tables show the results of borings at these two locations:

Borings at Dodson dam site, Montana.

Hole No.	Location.	Depth in feet.		Remarks.
		To rock.	Total.	
1	A 500	66.8	104.0	
2	A 600	70.5	104.3	
3	A 396	59.0	98.5	
4	A 448	59.3	100.0	
5	A 342	61.4	100.5	
6	B 328	65.1	100.0	
7	B 528	65.5	66.3	
8	B 396	56.1	95.8	
9	B 460	63.1	100.0	
10	A 710	110.1	125.2	
11	A 800		9.0	Trench.
12	875 west 100		30.0	
13	975		11.0	Do.
14	1,075 west 100		12.0	Do.
15	975 west 100		39.0	
16	1,075 east 100		15.0	Do.
17	1,225 west 100		15.0	Do.
18	875 east 100		16.0	Do.
19	1,325 west 50		8.0	Do.
20	1,325 east 100		14.0	Do.
21			7.0	Do.
22	1,023		13.0	
23	975 east 100	80.0	91.0	
24	1,025		14.0	Do.
25	1,175 east 50		12.0	Do.
26	1,175 east 100	73.0	94.0	
27	1,075		28.0	
28	1,225		65.0	
29	1,325		65.0	
30	1,325 west 100		50.0	
31	875		68.0	
32	1,025 west 50		60.0	
33	925 west 50		60.0	
34	925 east 50		38.0	

Borings on Malta south canal, at Rocky Point, Montana.

No.	Depth.	Remarks.
	Feet.	
1	39	Clay and sandstone.
2	30	Do.
3	41	Do.
4	23	Do.
5	35	Do.

During the current year surveys have also been made for two canals leading from Bowdoin reservoir along the north and south sides of Milk River, known, respectively, as the Bowdoin north and Bowdoin south canals. The following table shows the total acreage controlled by the various canal systems leading from Dodson dam:

Area controlled by canals east of Dodson.

	Acres.
Malta, south	20,671
Malta, north	14,021
Beaver Creek	13,894
Bowdoin, north	46,127
Bowdoin, south	48,370
Hinsdale Branch	13,723
Mud Lake outlet	2,094
Total	158,900

The construction of the Bowdoin reservoir will necessitate rebuilding about 20 miles of the track of the Great Northern Railway. Various private interests, including a reservoir filing on the lake, will also have to be purchased, so that the cost of the reservoir, outside of the necessary construction work, will be very great.

The discovery of the Chain Lakes reservoir site has resulted in the virtual abandonment, at least for a number of years, of the Bowdoin reservoir. It will not necessitate important changes, however, at the Dodson diversion dam. The Malta south canal, instead of being a feed canal to the reservoir, will now be reduced somewhat in size and will act simply as an irrigation canal to serve lands below during the irrigation season.

BEAVER CREEK STORAGE.

In connection with the settlement of the private claims on Bowdoin Lake, surveys were begun this year along upper Beaver Creek to discover, if possible, any reservoir sites that might exist. One of large capacity was found, the dam site being located in T. 28 N., R.

32 E., sec. 12. The following table shows its capacities to different contours:

Capacities of Beaver Creek reservoir at different contours.

Contour.	Area.	Capacity between contours.	Total capacity.	Length of dam.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*	*Feet.*
2,240	25	....	....	60
2,250	157	910	910	100
2,260	1,299	7,281	8,191	5,000
2,270	4,211	27,552	35,743	5,590
2,280	7,027	56,190	91,933	5,850
2,290	9,637	83,318	175,251	6,100
2,300	11,920	107,785	283,036	6,900

An earth dam to the 2,280-foot contour, or 45 feet high, with a top width of 16 feet, a water slope of 3 to 1, and an outside slope of 2 to 1 would require 331,000 cubic yards of material.

Beaver Creek is a stream subject to occasional freshets, but during the greater part of the year it has no flow. Two gaging stations have been maintained on it during the present year, the measurements showing the annual discharge during 1904 to be 26,780 acre-feet.

The waters of this stream are used at present by a number of ranchers. Their method of diversion consists of building a dam in the creek and then allowing the water as it comes down in a flood to spread out over their land. There are five such dams in the creek, serving somewhere in the neighborhood of 10,000 acres.

In June, 1903, a decision was rendered in the district court regarding appropriations on this stream, whereby 2½ miner's inches to the acre were deemed necessary, as Beaver Creek was a flood stream and not a constantly flowing one. This quantity of water flowing for eight days would equal 1 acre-foot.

All of the appropriators of this creek were not included in the above-described suit, but this year a new one was instituted, which included nearly all the people taking water from this stream. The case has not yet been settled.

MUD LAKE RESERVOIR.

North of Lake Bowdoin is located a reservoir site mainly in T. 32 N., R. 32 E., known as Mud Lake site. It has not a large capacity compared to the Bowdoin or Chain Lakes sites, but will answer well for secondary storage. The following table shows its capacity:

Capacities of Mud Lake reservoir at different contours.

Contour.	Capacity between contours.	Total capacity.
Feet.	*Acre-feet.*	*Acre-feet.*
2,195	0	0
2,200	7,302	7,302
2,205	9,469	16,769
2,210	11,280	28,049
2,215	14,667	42,716
2,220	18,974	61,690
2,240	99,220	160,910

At the outlet of this reservoir the topography is very complicated, and it requires a good topographic map to determine the best location of the dam. This area was being mapped at the close of the field season, and the data will be completed shortly for winter computations.

SUMMARY.

The complete system for lower Milk River Valley will consist of, first, the Chain Lakes reservoir, to store the waters of Milk River (and of St. Mary River, if arrangements with Canada are made for bringing St. Mary water through that country), and perhaps of Marias River; second, diversion canals near Yantic and Chinook; and, third, diversion canals on the north and south sides of Milk River at the Dodson dam to serve the lands to the east.

REPORT OF BOARD OF CONSULTING ENGINEERS.

In September, 1904, an examination was made of the reclamation projects in northern Montana by a board of consulting engineers consisting of Arthur P. Davis, George Y. Wisner, and H. N. Savage, which reported on September 19 as follows:

ST. MARY-MILK RIVER PROJECT.

This project involves the storage of water in St. Mary Lakes and its conduction to North Fork of Milk River by means of a canal 27.4 miles long. The water is then to flow down Milk River through Canada into Montana, to be used in lower Milk River Valley. In order to utilize the diversion canal to its full capacity and to provide a satisfactory water supply for the lands to be irrigated it is necessary to have a large storage reservoir in the lower Milk River Valley. For this purpose complete surveys have been made of Bowdoin Lake near Malta. This reservoir belongs to private parties, who are very unreasonable in their demands for its use. It also necessitates the removal of about 11 miles of railroad, which would be expensive and troublesome. The obstacles threatened to delay the whole project or render its feasibility doubtful. Fortunately, however, the topographic surveys have disclosed the existence of a reservoir site on Milk River at Chain Lakes above Havre, entirely in Montana, on which surveys are now in progress, and which appears to be a feasible site, with perhaps 300,000 acre-feet storage capacity. This has removed the most serious obstacle to the project from an engineering standpoint.

The only remaining difficulty of importance is the possibility of the diversion of St. Mary water while flowing through Canada in Milk River. To remove this danger an international agreement should be arranged by which the Canadian government will undertake to protect the delivery of stored water through Milk River.

* * * * * * *

It should be made clear that under no circumstances can stored water be demanded during the months of January, February, March, April, and May, or, in other words, that during those months the Canadian canal is entitled to take from Milk River only such water as may be flowing in Milk River at the time in its natural state, without increment from the St. Mary canal, or up to 330 second-feet, less that previously appropriated in Montana.

It should also be emphasized that any recognition of rights for the diversion of water from Milk River are necessarily subject to the prior rights of inhabitants of Milk River Valley in Montana. * * * Neither the American nor the Canadian Government has the right to interfere with prior appropriations either from St. Mary or Milk River.

It is important that a satisfactory agreement be entered into along the above lines as early as possible, as such will remove the chief remaining obstacle in the way of the construction of the St. Mary project.

The water supply for this project is considered sufficient for approximately 200,000 acres of land, and it will require about 160,000 acres of irrigated land to pay for the project. The data regarding irrigable lands are not complete, but it is known that more than 160,000, and possibly 200,000, acres can be reached by diversion from Milk River. Of the area reached, however, more than one-half is private land, part of which is already irrigated. The project is not feasible unless a large majority of the private land covered contribute to the cost. It is important, therefore, that the disposition of the landowners on this point be ascertained at the earliest possible moment. A portion of the irrigable land is on the Fort Belknap Indian Reservation, and as soon as matters are arranged with Canada legislation should be secured to render these lands available for irrigation under the provision of the reclamation act.

The elimination of the change in location of the Great Northern Railway at the diversion site near Dodson has been provided for, and if the expectations of the Chain Lakes reservoir are realized the removal of tracks from the Bowdoin reservoir site will not be necessary for this project.

According to appointment, the board was met by representatives of the Great Northern Railroad, who informed the board of the results of the surveys and estimates of the cost of the removal of their railroad track. No specific declaration of policy was made by the railroad people regarding the division of costs for relocation of track, and no recommendations on that point can be made now. The St. Mary-Milk River project is feasible with the removal of the difficulties mentioned.

MARIAS PROJECT.

The Marias project involves a diversion dam of earth 195 feet high, with some additional height to provide necessary storage on the top of the lake. The canal would be more than 17 miles long before reaching any irrigable land, and from that point would command probably 200,000 acres of land on Lonesome

Prairie, and its waste waters would drain into Milk River and be available for irrigation there. A reservoir site has been found at Lonesome Lake, in the midst of the Lonesome Prairie. Storage to the amount of about 75,000 acre-feet can also be provided in Two Medicine Lake, on the headwaters of the Marias. It is probable that the water supply and storage facilities of the project will provide irrigation for over 250,000 acres, which may be used either on Lonesome Prairie or in Milk River Valley, wherever most needed. It appears probable that if the Canadian government does not make satisfactory guaranties to justify the construction of the St. Mary reservoir and canals, the Marias drainage basin can be made to serve all available land in Milk River Valley and an additional area on Lonesome Prairie. The investigation on Marias River can probably be completed this year, and enough will be known to determine its approximate cost and the acreage it will serve. It is probable that the acreage cost will be greater than that of the St. Mary.

C. C. Babb, district engineer, has been requested to obtain the following information, named in the order of its importance:

1. Additional available acreage to be irrigated in Milk River Valley.
2. The capacity and cost of Chain Lakes reservoir.
3. Capacity and cost of Lonesome Lake reservoir.
4. Area of available land under Marias canal.
5. Area of available land under Lonesome Lake reservoir.
6. Area of lake formed by diversion dam on Marias River.
7. Completion of borings at Marias diversion.

RECOMMENDATIONS.

The board makes the following recommendations:

1. That steps be taken as soon as possible to obtain from the Canadian government a guaranty of the use of Milk River channel for the conduction of St. Mary waters.

2. That the district engineer be instructed to announce to the people of Milk River Valley that, subject to suitable arrangements with Canada, the irrigation of Milk River Valley is feasible and will be undertaken as soon as a sufficient acreage of private lands are pledged to return their proportion of the cost of the project. and for this purpose they are advised to form an organization of landowners to obtain pledges of land for the above purpose, and that it is desirable that 100,000 acres of land be pledged, and absolutely necessary that at least 70,000 acres be thus pledged.

3. That as soon as the proper arrangements with Canada can be made and the proper acreage of land subscribed steps be taken to acquire the necessary right of way and to let contracts for construction.

4. If proper arrangements can not be made promptly with Canada, it is recommended that the investigation of the Marias be completed as soon as possible, with a view to irrigating Milk River Valley from that source.

SUN RIVER PROJECT.[a]

The surveys of the Sun River project, made in 1889 and described in the Thirteenth Annual Report of the Geological Survey, part 3, showed in a general way some of the possibilities of reclaiming the bench lands lying between Sun and Teton rivers. Detailed surveys were made of 10 reservoir sites, the vacant lands affected were withdrawn from entry, and their status remains unchanged to-day. A small amount of the land to be flooded was in private ownership.

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[a] From report by S. B. Robbins.

The present investigations have not progressed far enough to determine just which, if any, of the 10 reservoirs it will be advisable to use. It is certain they will not all be needed, and it is probable that only a small area of private lands will have to be acquired. A general map of the Sun River project is published herewith as Pl. XXIX.

TOPOGRAPHY.

After leaving the Rocky Mountains at the southwest corner of T. 22 N., R. 8 W., Sun River flows southeastward to the NW. corner T. 20 N., R. 5 W., whence it flows almost due east, crossing and recrossing the fifth standard parallel north to its confluence with Missouri River at Great Falls, in T. 20 N., R. 3 E.

Teton River runs approximately parallel to the Sun, crossing and recrossing the sixth standard parallel north, emptying into Marias River in T. 25 N., R. 10 E., about a mile from the Missouri.

Deep Creek, one of the Teton's principal branches, heading in the foothills of the main range, runs northeastward, joining the main stream near the town of Choteau, in T. 24 N., R. 4 W. North Fork of Sun River and Deep Creek are only about 6 miles apart in R. 8 W.

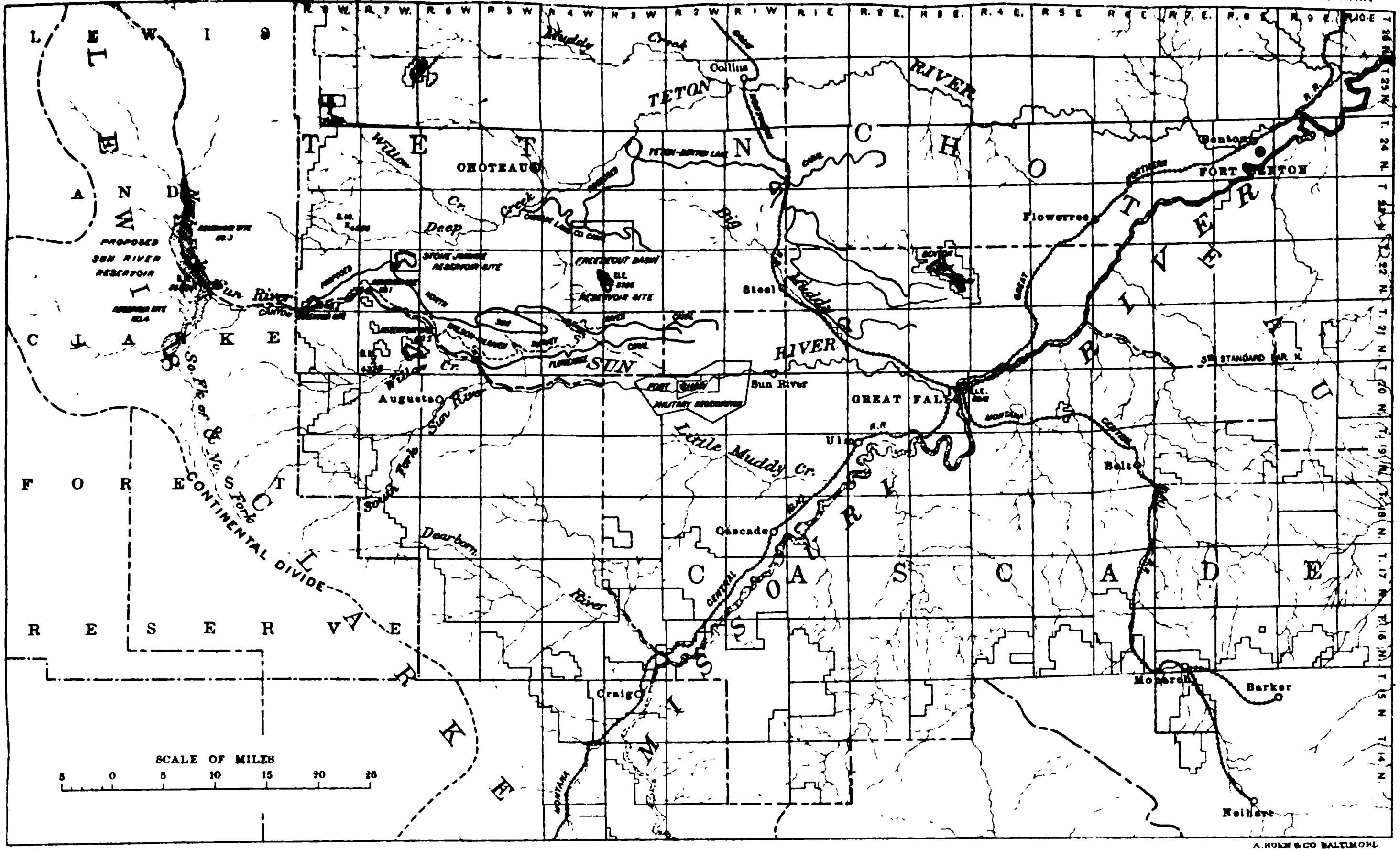
The Sun-Teton bench is divided into two practically equal parts by Big Muddy Creek, which rises in T. 23 N., R. 2 W., and runs southeastward into the Sun. These parts are topographically similar in that each contains a large lake basin located approximately in its center. The lake basin proper of the west part is known as Freezeout basin and the land sloping toward it as Freezeout bench. Similarly, to the east we have Benton Lake basin and Benton Lake bench. Surrounding these benches we have the Teton slope to the north, the Sun slope to the south, and the Missouri slope to the east.

The country near the foot of the mountains is a succession of rolling hills and hollows of glacial drift. As this gravel overlies the sandstones and shales of the bench country it gradually disappears as the general elevation lowers to the east, the soil of the benches varying from a more or less sandy loam to a heavy adobe clay.

There are approximately 960,000 acres in the tract between the rivers. At least half of this is too high or too rough to be reclaimed. The results of the preliminary surveys of the field season of 1904 have not been worked up, but it is believed that they will show over 200,000 acres in this area capable of reclamation, a very large percentage being vacant land.

WATER SUPPLY.

Gagings were made of North Fork of Sun River in 1889–1891, and others were begun in October, 1903, and are being continued. From the gagings, drainage basin, precipitation, and estimated run-off it is


LEWIS AND CLARKE FOREST RESERVE
TETON
CHOUTEAU
CASCADE
MISSOURI
RIVER
PROPOSED SUN RIVER RESERVOIR
CONTINENTAL DIVIDE
So. Fk. or & No. S Fork
Sun River
Willow Cr.
Deep Creek
Muddy Creek
TETON RIVER
Big Muddy Cr.
SUN RIVER
Little Muddy Cr.
Dearborn River
South Fork Sun River
Collins
Choteau
Steel
Sun River
Augusta
Great Falls
Ulm
Cascade
Craig
Belt
Flowerree
Benton
Fort Benton
Monarch
Barker
Neihart
FORT SHAW MILITARY RESERVATION
FREEZEOUT BASIN RESERVOIR SITE
STONE JOHNSON RESERVOIR SITE
3RD STANDARD PAR. N.
R. 9 W. R. 8 W. R. 7 W. R. 6 W. R. 5 W. R. 4 W. R. 3 W. R. 2 W. R. 1 W. R. 1 E. R. 2 E. R. 3 E. R. 4 E. R. 5 E. R. 6 E. R. 7 E. R. 8 E. R. 9 E. R. 10 E.
T. 26 N. T. 25 N. T. 24 N. T. 23 N. T. 22 N. T. 21 N. T. 20 N. T. 19 N. T. 18 N. T. 17 N. T. 16 N. T. 15 N. T. 14 N.
SCALE OF MILES
5 0 5 10 15 20 25
A. HOEN & CO. BALTIMORE

GENERAL MAP OF PROPOSED SUN RIVER PROJECT, MONTANA.

considered that the total annual water supply of North Fork is about 570,000 acre-feet.

The South Fork low-water flow is all appropriated and no gagings have yet been made to determine its floods. It enters the main stream too low to be available for diversion to the north benches and will be investigated in connection with the south-side lands.

The Teton has not been gaged by the Survey, but gagings made by private parties indicate a flood excess of 80,000 to 100,000 acre-feet annually over the amount now appropriated, which includes the total low-water flow.

NORTH FORK OF SUN RIVER.

In 1884 some Helena capitalists started construction of a canal to divert water from North Fork, in T. 22 N., R. 7 W., sec. 28, and carry it out toward Freezeout bench, but work was soon abandoned. In 1889 the Wilson canal No. 1 was surveyed over the same route. About 1902 a number of settlers filed homestead and desert claims on Freezeout bench, organized the Kilraven Cooperative Canal Company, and took up the same project to reclaim their lands. They have roughed about 4 miles of the 40 necessary to reach the bench, but at present work is at a standstill.

In July H. C. Hurd, assistant engineer, with a party was started on a preliminary survey of this line, the topography being taken by plane table and mapped on a scale of 500 feet to an inch. This survey was made because it was understood that no data of the earlier surveys are in existence other than a printed report, in which the estimates are very rough and the prices unsuited to present conditions, and also because it was believed that a much better line could be had, and it was therefore thought advisable to have data on hand to use in comparative estimates.

The survey was started about 1½ miles above the old one, at the dam site of reservoir No. 1, in order to obtain a feasible point of diversion in solid rock, the old one being very poor for a large canal, there being practically no bank on the south side of the river. In the report a 10-foot weir was planned for this point. If it were built it would have to extend half a mile across the bottoms to the bluff on the south. The survey was carried 40 miles until the height of the level bench was attained. For practically the whole distance the line skirts the edge of the gravel bluff. No estimate of cost has yet been made, but it is plain that it will be very high. Further, the seepage through the gravel along that stretch would be enormous. Current-meter measurements were taken along the Flowerree ditch, which parallels this line part of the way at a lower elevation, and, though puddled, a loss of 25 per cent in 4 miles was found. Sun River at this point carries no silt except a trifling amount at flood, and this is not of a character to stop seepage. There is little material in the neighborhood for puddling.

Upon completion of this survey Mr. Hurd moved up to North Fork Canyon and carried another survey through as far east as the Big Muddy, covering the highest land possible to reach. Determination of size of canals, acreage reclaimable, and cost have been of necessity postponed until completion of the season's field work and will be considered during the winter.

It is probable that the plan adopted will be to build a masonry diversion weir in the canyon at a point where it is only 4 feet wide at the water's edge and 15 feet wide at the crest of the weir, 60 feet above water. At this point the depth of water is 65 feet. Detailed surveys on a scale of 50 feet to 1 inch were made of the canyon, and the plan of diverting by a lower but longer weir above the falls will be estimated and considered, as will also the feasibility of making the diversion and attaining the elevation by constructing the dam at No. 2 reservoir.

The reason for diverting in the vicinity of the canyon is to get the elevation to carry the water across into Deep Creek and thence into Freezeout basin. This divide is reached at the fifteenth mile, and what water is desired will flow down natural channels toward the Teton. Its use will be mentioned later.

Below the level of the main canal and before turning the water into the coulee en route to Deep Creek is a lake bed which may be utilized for storage by making two small earth fills and a short tunnel through earth for drainage. The capacity has been approximately estimated to be about 40,000 acre-feet. It is named the Stone Johnnie reservoir. Surveys were made of this, and estimates will be worked up.

At about the twentieth mile the summit of the bench on the Sun slope is attained and the first considerable area of reclaimable land is reached. Thence this canal will irrigate good land for practically its entire length.

It is necessary to give this high-line canal several drops to make its grade conform to that of the country it traverses, and considerable power may be developed, some of which probably could be used to elevate water to small tracts of good land which can not be reached by gravity.

These two surveys meet at the controlling point in the divide between Sun slope and Freezeout slope, and thence eastward only one canal line was surveyed.

FREEZEOUT BASIN.

As it is possible to throw the water from North Fork of Sun River into Deep Creek, and also from the Teton into Willow Creek, a tributary of Deep Creek, and to take it up below the junction of these two creeks and put it into Freezeout basin, E. R. Childs, assistant engineer, with a party, was sent into that basin the latter part of July to make a contour survey of it to determine its capacity. An interval of 5 feet and scale of 1,000 feet to the inch was used.

Area and capacity of Freezeout basin at different contours.

Sea level datum, contour.	Area.		Capacity between contours.	Total capacity.
	Square miles.	Acres.		
Feet.			*Acre-feet.*	*Acre-feet.*
3,755	2.22	1,421	2,132	2,132
3,760	4.25	2,720	10,353	12,485
3,765	10.88	6,963	24,208	36,693
3,770	15.89	10,170	42,833	79,526
3,775	18.65	11,936	55,265	134,791
3,780	20.93	13,395	63,328	198,119
3,785	22.78	14,579	69,935	268,054
3,790	24.78	15,859	76,095	344,149
3,795	26.48	16,947	82,015	426,164
3,800	28.23	18,067	87,535	513,699
3,805	29.71	19,014	92,702	606,401
3,810	31.43	20,115	97,822	704,223
3,815	32.90	21,056	102,927	807,150
3,820	34.40	22,016	107,680	914,830
3,825	36.08	23,091	112,767	1,027,597

A detailed survey of the gap necessary to be closed to make a storage reservoir of this basin was made on a scale of 200 feet to 1 inch, with contour intervals of 2 feet. No estimate of cost nor size of dam has been made for the reason that canal surveys leading from the basin are not complete and it is not known what acreage is available for irrigation nor at what elevation it will be most economical to draw off the stored water. Data for these calculations will be available this winter.

The dam, if built, would be of earth, and the cost per acre-foot stored would be low. Plans for utilizing Teton waters in this connection will have to be considered before this reservoir problem can be definitely settled.

A canal 11 miles long was surveyed and topography taken to secure data for use in studying the matter of supplying Freezeout reservoir.

TETON-BENTON LAKE CANAL.

A canal survey is in progress from Freezeout reservoir along the natural outlet toward Teton and eastward along the Teton slope, to serve lands on the south side of that stream and also to cover the Benton Lake bench. The survey is being run on a grade of 1 foot in 5,000 and topography taken on a scale of 500 feet to the inch, with 5-foot contour intervals. There is a large acreage of excellent land lying below the line.

The Montana and Great Northern Railway runs up the Big Muddy through a gap in the Teton Ridge, thence across the river and to the north. This gap, which is the controlling point in the Teton-Benton Lake survey, is about 25 miles from the Freezeout site by the canal line. At the gap a bifurcation was made, one party carrying the line eastward down the Teton and another working south and east to determine how much of the Benton Lake bench can be covered. This line will do away with the flume across the Big Muddy, as proposed by the 1889 survey, will serve a large tract of land not considered heretofore along the Teton, and will strike a higher elevation on the Benton Lake bench than the flume line.

STORAGE IN THE MOUNTAINS.

Storage should be secured in the mountains in preference to using Freezeout basin. The objections to using Freezeout basin are its large area and shallow depth; the fact that its use will flood land which might better be irrigated, as the soil and topography are excellent for that purpose; the necessity of providing flood-water canals of large capacity to carry the Sun River floods 15 miles and Deep Creek water 11 miles to the basin; the low elevation of the basin, making it probable that a large body of dead water, possibly as much as a whole year's flood, would have to be perpetually carried in the lower part of the reservoir in order to gain a useful elevation. On the other hand, a great point in its favor would be the cheapness per acre-foot stored, as far as the cost of the reservoir in itself is considered.

Reservoirs No. 3 on North Fork of North Fork and No. 4 on South Fork of North Fork of Sun River, of the 1889 survey, are estimated to store about 72,000 acre-feet.

A brief reconnaissance was made of a dam site just below the forks of North Fork. The conditions indicate that a dam about 200 feet high at this point would store nearly half a million acre-feet, or the whole run-off of Sun River above that point. The river cuts through a hard limestone reef, and the bottom and abutments of a dam would be solid rock. The river is 40 feet wide and the crest of the dam would be about 400 feet long. There is practically no silt at all at that point, and there would be no question as to the length of time a reservoir would be useful. The proposed reservoir would back water up both forks to the head of reservoir No. 4 and several miles above the head of reservoir No. 3. It is planned to make detailed surveys of this location next season.

AREA SOUTH OF SUN RIVER.

No investigations or surveys were made south of Sun River in 1904. However, it is known that it is practicable to irrigate 100,000 acres lying between the Sun and the Missouri if water can be had in sufficient volume. Some water is available for use on the south side which can not be used on the north. Some reservoir sites are known to exist, and it is thought that others can be found. Altogether, the outlook on the south side is worthy of close investigation.

TETON RIVER.

The low-water flow of the Teton is practically all utilized, but little has been done toward storing the floods. They can be stored in a basin formerly reserved as reservoir No. 29 (which, through misconception of the possible uses to which it might be put, was approved for private use), and thence conveyed to bench lands on the north side of the river. Or it is possible to use the water in connection with Freezeout basin. In the first case the Teton would be a small project by itself; in the latter case it would join into the Sun River project. Future investigations will show the better course.

BITTERROOT VALLEY.[a]

LOCATION.

Bitterroot Valley is a narrow valley in western Montana, lying near meridian 114° 05′ W., and extending from latitude 45° 50′ to 47° N. It lies principally in Tps. 1 to 14 N., and Rs. 19, 20, and 21 W. of the principal meridian. The length of the valley from Lolo—12 miles above Missoula—at the north, to Como at the south is about 60 miles, and the average width of lands settled and partly cultivated is about 8 miles, including bench lands.

DRAINAGE AREA.

The drainage basin has an area of 3,260 square miles, including high mountain ranges on both east and west, those on the west rising to an average altitude of 8,000 feet above sea level. Large areas of these ranges are heavily timbered, and are included in the Bitterroot Forest Reserve. On the east the mountains are not so high nor so heavily timbered, rising only to an altitude of 6,500 feet. At present these forests are not protected, though they are now being inspected for the purpose of including them in a forest reserve.

RAINFALL, RUN-OFF, AND DRAINAGE.

The records of precipitation in this valley are meager and lack continuity. The best records have been kept at Missoula, in the lower

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[a] From report by E. T. Perkins.

(northern) end of the valley, a monthly mean for twenty-seven years given by the United States Department of Agriculture being as follows:

Average precipitation at Missoula, Mont.

January	1.56
February	.90
March	1.07
April	.98
May	2.17
June	2.11
July	1.06
August	.67
September	1.17
October	1.23
November	1.42
December	1.55

The annual mean is 15.91 inches. (The records for July extend over twenty years; for August, nineteen years; for September, twenty-one years.) Partial records have been obtained from volunteer observers at Derby, Grantsdale, Hamilton, and Corvallis, but have been too irregular to have much value. At Corvallis the total precipitation for 1899 is given as 5.36 inches, for 1900 as 9.75 inches, and for 1901 as 11.05 inches, with a minimum monthly mean temperature of 16.3°, in February, 1899, and a maximum monthly mean of 75.1°, in August, 1901. The lowest temperature recorded is —28°, at Florence, in February, 1899, the maximum 100°, at Corvallis, in July and August, 1901. The timber upon the slopes of this drainage holds the snow and general moisture, and the average high water is later than in other streams in neighboring parts of Idaho and Montana, extreme high water being in May and June. The estimated monthly mean for May is 11,025 second-feet; for June, 5,020; for July, 2,667, and for August, 995 second-feet, as determined at the gaging station near Missoula in 1901.[a]

The main Bitterroot River runs down the center of the valley, being formed above Darby, near Evelyn, by the junction of South Fork and East Fork, and empties into Missoula River about 4 miles below Missoula. The main tributaries are Weeping Child, Skalkaho, Burnt Fork, Threemile, and Eightmile creeks on the right, and Rock, Lost Horse, Big, and Carlton creeks and Lolo Fork on the left.

The following discharge measurements were made on Bitterroot River, at Grantsdale, Mont., during 1902, 1903, and 1904, and at Missoula, Mont., during 1903 and 1904, by the United States Geological Survey:

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[a] Newell, F. H., Progress of stream measurements for 1901: Water-Sup. and Irr. Paper No. 75, U. S. Geol. Survey, 1903.

Discharge measurements of Bitterroot River at Grantsdale, Mont.

Date.		Hydrographer.	Gage height.	Discharge.
1902.			*Feet.*	*Sec.-ft.*
Apr.	25	H. B. Waters	2.57	1,098
	25	.....do	2.55	1,055
July	11	.....do	3.38	2,424
Aug.	26	.....do	1.50	247
	26	.....do	1.50	247
Nov.	29	J. S. Baker	1.72	345
1903.				
Apr.	28	F. M. Brown	3.59	3,283
May	29	C. D. Flaherty	4.05	4,763
June	16	.....do	6.10	9,075
	24	.....do	4.50	3,914
July	9	.....do	3.50	2,308
Aug.	14	.....do	1.25	322
Sept.	9	.....do	1.35	338
Oct.	9	J. H. Sloan	2.36	647
1904.				
May	3	A. E. Place	4.60	4,453
	22	W. B. Freeman	6.45	9,340

Daily discharge, in second-feet, of Bitterroot River, near Missoula, Mont., for 1900.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1,255	1,255	....	1,930	....	7,210	3,570	950	1,080	1,165	1,880	1,123
2	1,165	1,255	....	2,040	....	7,355	3,260	950	1,080	1,080	1,930	1,123
3	1,123	1,255	....	2,540	6,400	8,100	3,110	930	1,010	1,080	1,930	1,123
4	1,123	1,165	910	3,085	7,070	9,000	2,680	910	950	1,165	1,730	1,123
5	1,165	1,045	930	3,570	8,700	9,600	2,540	890	950	1,165	1,635	1,165
6	1,165	1,010	930	3,810	9,600	10,200	2,475	870	1,010	1,123	1,635	1,165
7	1,165	980	980	3,975	10,800	10,650	2,475	870	1,045	1,165	1,445	1,255
8	1,165	950	1,045	3,730	10,500	9,300	2,475	870	1,045	1,210	1,350	1,350
9	1,123	950	1,080	3,490	9,750	8,700	2,280	870	1,010	1,210	1,540	1,255
10	1,080	980	1,080	3,410	10,950	7,800	2,220	870	1,010	1,165	1,350	1,255
11	1,080	(a)	1,255	3,335	12,650	6,400	2,220	870	1,010	1,165	1,255	1,165
12	1,123	(a)	1,303	3,260	14,638	6,150	1,930	853	980	1,165	1,210	1,123
13	1,165	(a)	1,350	3,335	18,150	6,150	1,830	853	980	1,080	1,210	1,080
14	1,350	(a)	1,445	3,260	15,200	5,910	1,830	853	950	1,045	1,165	1,080
15	1,540	(a)	1,493	3,260	11,700	5,910	1,730	853	950	1,045	1,165	1,080
16	1,540	(a)	1,683	3,410	10,200	8,700	1,635	853	950	1,010	1,165	1,080
17	1,445	(a)	1,830	3,730	10,350	8,250	1,540	853	1,350	1,010	1,165	1,165
18	1,398	(a)	1,930	4,145	10,500	7,800	1,445	853	1,350	1,045	1,165	1,165
19	1,350	(a)	1,985	4,230	10,650	7,500	1,398	935	1,350	1,045	(a)	1,255
20	1,350	(a)	2,040	4,320	9,600	6,795	1,398	935	1,255	1,030	(a)	1,255
21	1,255	(a)	2,040	4,410	8,400	7,210	1,255	800	1,255	1,165	(a)	1,255
22	1,210	(a)	2,100	4,600	8,700	7,500	1,210	800	1,255	1,255	(a)	1,255
23	1,210	(a)	2,100	4,410	8,400	7,650	1,165	800	1,210	1,350	(a)	1,255
24	1,210	(a)	2,160	4,230	8,250	7,500	1,165	835	1,255	1,445	(a)	1,165
25	1,123	(a)	2,160	4,060	8,100	7,800	1,123	835	1,255	1,165	1,255	1,165
26	1,123	(a)	2,280	4,060	8,100	6,660	1,123	835	1,350	1,540	1,165	1,165
27	1,123	(a)	2,160	3,975	8,250	5,670	1,123	853	1,350	1,730	1,165	1,080
28	1,165	(a)	2,040	3,975	8,250	4,800	1,123	870	1,350	1,780	1,165	1,010
29	1,165	....	2,100	....	8,250	4,230	1,123	870	1,255	1,780	1,165	950
30	1,165	....	1,930	....	7,355	4,060	1,010	950	1,255	1,830	1,123	950
31	1,255	....	1,930	....	6,795	....	980	1,010	....	1,880	....	950

[a] Ice.

Seepage test on Bitterroot River, from Grantsdale Bridge to Buckhouse Bridge.[a]

Length in miles.	Flow at upper end in second-feet.	Inflow in second-feet.	Total inflow in second-feet.	Outflow at lower end in second-feet.	Outflow diversions in second-feet.	Total outflow in second-feet.	Loss in second-feet.	Per cent of loss.	Loss per mile. In second-feet.	Loss per mile. Per cent.
JUNE 11-15, 1903.										
48	9,111.150	5,764.25	14,875.40	12,660.60	313.50	12,974.10	1,901.30	12.79	39.6	0.83
JULY 9-14, 1903.										
48	2,320.90	1,623.8	3,944.7	4,221.70	161.7	4,383.40	−438.7	−11.12	−9.1	−0.23
AUGUST 7-14, 1903.										
48	326.50	209.50	536.00	1,536.80	111.8	1,647.00	−1,111.0	−207.27	−23.1	−4.3

[a] Tests conducted by Samuel Fortier, irrigation expert, Department of Agriculture.

Daily discharge, in second-feet, of Bitterroot River, at Grantsdale, Mont., for 1902.

Day.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		1,020	7,790	2,650	790	205	205	280	395
2		1,150	7,325	2,450	790	175	205		395
3		1,020	5,900	3,050	700	175	205		395
4		900	5,665	3,050	700	175	240		395
5		900	5,220	3,700	615	150	240		395
6		1,020	4,790	3,255	615	150	240		340
7		1,430	4,790	3,050	530	135	240		395
8		2,265	5,220	2,650	530	135	280		395
9		3,700	7,100	2,265	460	135	280	395	395
10		5,005	9,285	2,450	460	150	280	395	530
11		5,440	7,555	2,650	460	150	280	395	530
12		5,900	6,855	2,850	460	135	280	395	460
13		6,380	6,380	2,650	395	135	240	340	460
14		7,790	5,900	2,450	395	135	205	340	395
15		8,970	5,220	2,265	395	135	205	340	460
16		8,340	4,790	2,265	395	150	205	340	530
17		6,855	4,355	2,085	395	150	205	340	395
18		5,665	4,575	2,085	395	175	240	340	395
19		4,790	3,700	1,910	395	150	240	340	395
20		3,920	3,700	1,745	395	175	240	340	530
21		3,470	3,700	1,745	340	175	240	340	530
22		3,255	3,920	1,745	340	175	280	340	530
23		3,255	4,790	1,585	340	175	280	530	530
24		3,700	5,005	1,585	280	205	240	615	530
25	1,020	4,140	4,355	1,430	280	205	240	280	[a]615
26	1,150	4,790	3,920	1,430	280	205	240	280	[a]1,150
27	1,150	7,100	3,700	1,290	240	205	240	280	460
28	1,150	8,970	3,470	1,150	240	205	240	280	460
29	1,020	11,075	3,255	1,020	240	205	240	340	460
30	1,020	8,970	3,050	1,020	205	175	240	340	395
31		8,340		900	205		280		395

[a] Ice gorge formed on December 26, went out on December 27.

Estimated monthly discharge of Bitterroot River at Grantsdale, Mont., for 1903.

[Drainage area, 1,550 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
January	700	395	518	31,850	0.334	0.385
February	530	395	471	26,158	.304	.317
March	1,150	340	519	31,912	.335	.386
April	3,050	615	1,409	83,841	.909	1.010
May	6,150	1,745	3,031	186,369	1.955	2.256
June	12,875	4,575	7,968	474,129	5.141	5.736
July	3,700	700	1,912	117,564	1.234	1.424
August	700	175	334	20,537	.215	.248
September	1,150	150	481	28,622	.310	.346
October	1,585	460	825	50,727	.532	.617
November	790	530	615	36,596	.397	.443
December	1,020	530	650	39,967	.419	.483
The year	12,875	150	1,561	1,128,272	1.007	13.651

Discharge measurements of Bitterroot River at Missoula, Mont.

Date.	Hydrographer.	Gage height in feet.	Discharge in second-feet.
1903.			
Apr. 25	Brown		4,131
May 23	Baker	3.40	3,377
May 29	Flaherty	4.05	4,763
June 1	.....do	7.05	9,982
15	.....do	8.20	12,637
29	.....do	6.86	9,121
July 9	.....do	3.50	2,308
12	.....do	4.45	4,217
Aug. 10	Cowan	2.30	1,546
14	Flaherty	1.25	322
Sept. 9	.....do	1.35	338
13	Cowan	2.70	1,463
Oct. 8	Sloan	2.90	1,683
1904.			
Apr. 28	A. E. Place	5.26	8,641
May 20	W. D. Freeman	7.00	9,883
28	E. C. Murphy	7.20	10,394

UTILIZATION OF STREAMS.

The entire flow of all the tributary streams has been appropriated and is used mostly upon the benches and higher lands back from the river bottoms. A large part of the river flow is in use, but apparently there is sufficient water unappropriated to irrigate the remaining lands of the valley. This could unquestionably be done were it possible to make an exchange of water, and use the water from the tributary streams only upon the higher lands and the water from the river upon the bottom lands, but to this the ranchers owning water rights on the creeks seem reluctant to agree.

RESERVOIRS.

Were it necessary to supplement the river discharge by the storage of flood waters, probable reservoir sites exist at Lake Como, on Rock Creek, and at Big Creek Lakes, on Big Creek. Lake Como has a present surface area of about 265 acres, and Big Creek Lakes are about 2¼ miles long, averaging one-third of a mile in width. The water level of either of these lakes can be raised by a short dam. There are also several small reservoirs on the tributary creeks, particularly on Burnt Fork and Eightmile Creek.

LAND AREAS AND OWNERSHIP.

As indicated in the plats in the surveyor-general's office, there are 307,299 acres of bench and bottom lands in this valley, located by townships as follows:

Lands in Bitterroot Valley, Montana.

	Acres.
7 N., 19 W	9,050
8 N., 19 W	18,117
9 N., 19 W	19,182
10 N., 19 W	17,880
11 N., 19 W	5,205
13 N., 19 W	19,884
5 N., 20 W	11,958
6 N., 20 W	22,736
7 N., 20 W	22,966
8 N., 20 W	22,920
9 N., 20 W	18,285
10 N., 20 W	11,064
11 N., 20 W	8,274
12 N., 20 W	10,663
13 N., 20 W	16,198
14 N., 20 W	21,454
5 N., 21 W	8,641
6 N., 21 W	10,399
7 N., 21 W	11,041
8 N., 21 W	5,160
14 N., 21 W	7,474
15 N., 21 W	8,748
Total	307,299

Of the above area 27,680 acres are owned by the State of Montana, classified as grazing and agricultural lands, principally in the following townships:

Lands in Bitterroot Valley owned by State of Montana.

	Acres.
6 N., 19 W	320
7 N., 19 W	1,920
8 N., 19 W	2,859
9 N., 19 W	3,040
10 N., 19 W	7,240
6 N., 20 W	960
7 N., 20 W	4,860
8 N., 20 W	1,200
9 N., 20 W	1,320
10 N., 20 W	640
11 N., 20 W	320
Total	24,679

Only a small percentage of this land can be irrigated by a high-line ditch.

The State also owns 13,320 acres of timber land in Bitterroot Valley. Of the bottom lands and bench lands there are somewhat over 75,000 acres in total or part cultivation, and upon an additional area of probably 10,000 acres dry farming of grain is carried on with a considerable amount of success, 25 bushels of wheat being an average crop per acre. The remaining parts of valley that might be reclaimed are nearly all in private ownership, and it does not appear that either the State or the Federal Government would materially profit by a reclamation project.

PRESENT CANALS.

At the present time there are several canals taking water from the Bitterroot River.

The upper canal is the Hedge ditch, owned by the Marcus Daly estate, which sells water at $1.25 an inch, measured according to Montana law, which prescribes that 1 second-foot shall be equal to 40 inches. This ditch has a present capacity of 100 second-feet, limited by the size of the flumes, which are 4 by 8 inches inside measurement. It is proposed to increase the flumes to 6 by 12 inches, which would about double the carrying capacity of the ditch, that portion of the ditch in excavation being of sufficient size to carry the added amount of water. The intake of the Hedge ditch is very close to the center of sec. 11, T. 4 N., R. 21 W. of the principal meridian, at an approximate elevation of 3,700 feet above sea level.

Next below the Hedge ditch is the Republican ditch, also owned by the Daly estate. This ditch has a capacity of 120 second-feet; its intake is in NW. ¼ sec. 25, T. 5 N., R. 21 W. of the principal meridian, at an approximate elevation of 3,610 feet, where a crib dam and headworks have been constructed. There is no regular grade maintained in either the Hedge or the Republican; for 8 miles the Republican has the grade of the valley, which is here estimated to be 50 feet per mile. Even then the two ditches are within 100 feet horizontal distance of one another in sec. 15, T. 7 N., R. 20 W., and at very nearly the same elevation above sea, so that there is a heavy waste of grade in the Hedge ditch.

Below the Republican ditch are the Ward ditch and Skalkaho ditch from Skalkaho Creek, and the Surprise ditch, the Supply ditch, the Union ditch from the river, besides many minor ditches from both the river and the tributaries on either side. The waste through seepage and evaporation of these many small ditches and the added cost of maintenance over one large ditch are very apparent.

DUTY OF WATER, SEEPAGE, EVAPORATION.

Ordinary usage is 1 inch to 1 acre (40 inches equal 1 second-foot) or about 8 acre-feet during the season, but this is self-evidently a waste of water, as the lower lands are suffering from seepage, and alkali is being brought to the surface in many of the lower orchards and fields. J. B. Humphery, of Stevensville, estimates 300 inches sufficient for 320 acres. The United States Department of Agriculture, whose investigations cover 150,000 acres, affirms that one-half inch to an acre is ample. Burt E. Palmer, division superintendent of the Northern Pacific Railroad, estimates that 1 cubic second-foot is sufficient for 160 acres. This is the same as the duty of water in Yakima Valley, Washington. G. M. Powers, manager of the Calmono Orchard Company, estimates that one-half inch of water is sufficient for 1 acre of orchard.

There are no reliable observations concerning seepage and evaporation, but it is estimated that on the Republican ditch, which flows through a gravelly soil, the loss is 28 per cent in 13 miles. On the other ditches, which have long lengths of flume and which gain by seepage from upper ditches, the loss is estimated as 10 per cent in about 10 miles.

SEASON OF IRRIGATION.

The first irrigation takes place about April 1, and the last about September 15, the irrigation period extending over five and one-half months. The farmers of Burnt Fork begin irrigating May 15 and continue to September 1, a period of three and one-half months, governed principally by the water supply. They would continue to October 1 if it were possible. G. M. Powers, manager of the Calmono Orchard Company on Eightmile Creek, estimates that the period of irrigation is from April 15 to September 15, when fall rains ordinarily begin. According to Mr. J. B. Humphery, of Stevensville, the waters of Burnt Fork begin to fall about June 25, there being from 300 to 400 second-feet in the stream during high water. The same authority states that one irrigation lasts three weeks upon the bench lands of Burnt Fork, where a substratum of clay holds the water. The land in the Burnt Fork bottoms is more porous, and requires more frequent irrigations.

CROPS, COST OF PRODUCTION, VALUES.

The ordinary crops of the Bitterroot Valley are well represented by the following list of crops of the Daly Bitterroot stock farm, of 22,000 acres, and of the Ravalli farm, of 1,100 acres, furnished by P. J. Shannon, manager:

Crop acreage, Bitterroot stock farm, 1904.

	Meadow.	Wheat.	Oats.	Barley.	Pease.	Pasture.
Prendergast	1,714.0	330.0	47.2			253.0
Gilchrist	1,925.0	109.0				221.0
Hamilton	1,457.0	111.0	82.0		27.0	521.0
Johnson	932.0	424.0	90.3	64.6	9.0	344.0
See	248.0	60.0	30.2			25.0
Jo Bush	100.0	42.0	8.5			
Ravalli farm	712.0	74.0	64.8			69.5
Total	7,088.0	1,150.0	323.0	64.6	36.0	1,433.5

	Orchard.	Vegetables.	Roots and nursery.	Meadow in orchard.	Total acreage in grain.	Total acreage in cultivation.
Prendergast	38,5	10.3		38.5	377.2	2,393.0
Gilchrist	76.7	8.5	9.5	60.0	109.0	2,349.0
Hamilton	81.5	9.3		81.5	220.0	2,288.0
Johnson	70.0	7.1		10.0	587.9	1,941.0
See		3.0			90.2	366.0
Jo Bush	1.5				50.5	152.0
Grantsdale						263.0
Quarantine						38.0
Crabb						21.0
Ravalli farm	8.0				139.6	929.0
Total	276.2	38.2	9.5	190.0	1,574.4	10,740.0

The cost of production of the various crops is furnished by the same authority, and is as follows:

Cost of production, Bitterroot stock farm.

		Quantity.	Cost per unit.
Haying	tons	9,813	$1.47
Baling	do		2.00
Hauling	do		1.00
Harvesting	bushels	98,582	.04½
Irrigation	acres	9,309	.94¼
Plowing	do	11,215	2.25
Harrowing	do	2,804	.48
Seeding	do	2,804	.42½
Rolling	do		.08

Yield per acre of Bitterroot stock farm.

Hay	tons	2
Oats	bushels	40
Wheat	do	30

The average net profit is $10 per acre on grains and hay, which is worth from $8 to $15 per ton f. o. b. at Hamilton. These figures are reliable, as close book accounts are kept on these farms.

Orchards have been experimented with on a large scale and have proved but moderately successful, especially on the lowlands. Up to date no worms or codlin moths have appeared in this valley. On the Daly ranch there have been large areas of orchard that have been turned back into fields. At Eightmile Creek the Calmono Fruit Company has endeavored to raise and operate orchards without irrigation, but the effort has been unsuccessful. The trees grow, but the fruit does not mature. Sugar beets have been successfully raised, experimentally, giving a large crop per acre and a high per cent of sugar.

VALUE OF LAND.

A general consensus of opinion gives the following values of land:

Value of land, per acre, in Bitterroot Valley.

Bench land, nonirrigable (for pasture)	$1.25 to $5.00
Bench land, dry farming (for grain)	10.00
Bottom land, irrigable, with water rights (for general crops)	40.00
Orchard lands, bearing, with water rights	150.00 to 250.00

POSSIBLE RECLAMATION PROJECTS.

There are several possible projects in this valley, but in every case 90 per cent of the land is in private ownership.

The largest project covers the reclamation of the bench lands, locally known as New Oklahoma, that lie in secs. 2, 3, 10, 11, 12, 13, 14, 15, 22, 23, 26, 27, T. 7 N., R. 20 W. of the principal meridian, about 8,000 acres; the unirrigated areas of the south bench, 6,000 acres; of the north bench, 3,000 acres, and of the bottom lands of Burnt Fork, 10,000 acres; the lands of Threemile Creek bottom, 6,000 acres; the lands of Eightmile Creek bottom, 4,000 acres; the bench lands below Eightmile Creek, 10,000 acres, and about 10,000 acres on the smaller benches and bottoms; in all, possibly 57,000 acres which might be irrigated by a combination of ditches from the tributary streams and the river. On the west side of the river opposite Victor are a number of tracts of land composed equally of bench and bottom, possibly amounting to 25,000 acres, that might be irrigated by a combination of ditches from the high streams and the river.

At Missoula, on the left bank, between Missoula and Bitterroot rivers, is a tract of possibly 10,000 acres that might be irrigated from either the Bitterroot, with a diversion point 10 miles above Missoula, or from the Big Blackfoot, with diversion at the railroad bridge at Bonner. A 30-foot dam in Missoula River at Missoula would serve same purposes. The Missoula, formed by the junction of Hell Gate and Big Blackfoot rivers, has a drainage area of 5,960 square miles. There is less snow and a more speedy run-off than on the Bitterroot watershed. The estimated monthly mean flow is: May, 15,156 second-feet; June, 7,450 second-feet; July, 2,815 second-feet, and August, 1,300 second-feet.

Below Missoula, on the north bank, between Missoula and Frenchtown, a distance of 18 miles, is a valley partly irrigated and partly dry farmed. A ditch delivered at the junction of the Missoula and the Bitterroot irrigates 8,000 acres. An additional area of 17,000 acres could be irrigated by a high-line ditch.

The sum total of possible irrigation projects is as follows:

Total irrigable lands in Bitterroot Valley.

	Acres.
East side of Bitterroot Valley	57,000
West side of Bitterroot Valley	25,000
South of Missoula	10,000
Between Missoula and Frenchtown	17,000
Total	109,000

The total acreage of the valley may be divided as follows:

Total lands in Bitterroot Valley.

	Acres.
Irrigated lands (above Missoula)	75,000
Irrigated lands (below Missoula)	8,000
Dry farming	10,000
Irrigable lands	109,000
Grazing and timber lands	105,299
Total	307,299

The two projects at or below Missoula appear to be subjects for private investigation and investment. The project on the west side of Bitterroot Valley can be covered by a ditch now in course of construction, the Ward ditch, and only the project on the east side of the river remains to be considered as Federal work under the direction of the Geological Survey.

EAST SIDE PROJECT OF BITTERROOT VALLEY.

A ditch to serve the lands upon the east side of Bitterroot Valley must be diverted at an elevation of 3,750 feet above sea level, and maintain as high an elevation as possible. The present Hedge ditch, diverted at an approximate elevation of 3,700 feet, would cover a major portion of the land under discussion were the slope lowered and a new location adopted after the first few miles.

To divert at an elevation of 3,750 feet would require a diversion about the center of sec. 26, T. 4 N., R. 21 W., and a length of flume or heavy side-hill construction for 6 or 8 miles or else a 60-foot dam at the present point of diversion of the Hedge ditch. Here the valley narrows to about 2,200 feet and offers the only possible high dam site in the valley. On the right bank there is rock, but the left bank is only a gravel bar about 100 feet high. There appears to be bed rock in the river, but no available spillway exists. All three propositions being duly considered, it seems best to adopt the present diversion of the Hedge ditch and to make a location to save all grade possible. There will be heavy side-hill construction during the first few miles and several heavy creek crossings, but from a superficial examination this seems the best plan.

The cost of the Hedge ditch was very near $100,000, against an estimated cost of $60,000. The costs of labor were:

Cost of excavation and construction of Hedge ditch.

Gravelly material	per cubic yard	$0.15
Solid rock	do	1.00
Loose rock	do	.70
Pick and shovel work	do	.35
Flume, 4 by 8 feet 3 inches[a]	per linear foot	2.00

CONCLUSIONS.

This land being nearly all in private ownership, the initiative steps should be taken by the citizens of the community.

There is relatively but a small area of the valley which is not already reclaimed in whole or part by private enterprise.

The greatest good to the entire valley and the complete reclamation of all of its lands would result from a consolidation of all interests and from providing water storage and more completely distributing the water supply.

This can be brought about possibly under the terms of the reclamation act, but the initiative must be taken by the present landowners, there being a very small proportion, if any, of public lands reclaimable.

To economically store and distribute the available supply it will be necessary to acquire and merge many vested rights. The extent and value of these must be ascertained as an essential preliminary.

If the initiative is taken by the landowners and an effective water-users' association is formed to ascertain and acquire the necessary rights and furnish details, further surveys will be made to obtain data upon which to base accurate estimates of probable cost.

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[a] Lumber, $6 per M feet.

CROW RESERVATION PROJECT.[a]

LOCATION.

The lands to be irrigated under the Crow Reservation project are in southwestern Montana and lie mostly inside the present limits of the reservation; a large part of them are within the ceded strip, which will be opened to settlement under the provisions of the act of Congress approved April 27, 1904. They are adjacent to the Yellowstone and Bighorn rivers, and it is proposed to irrigate them by a system depending on these rivers for the water supply. Their altitude varies from about 2,700 to 3,300 feet above sea level. The principal town and supply point for the region is Billings, which is situated in the Yellowstone Valley on the Northern Pacific Railway and at the terminus of the Burlington route. Billings is about 8 miles west of the reservation line. Forsyth, on the Northern Pacific Railway, is a few miles east of the reservation and would be the supply point for the Yellowstone Valley below the mouth of the Bighorn.

GENERAL DESCRIPTION.

The irrigable lands lie in the Yellowstone Valley on the south side of Yellowstone River and in the Bighorn Valley on the west side of Bighorn River.

During the present season of 1904 preliminary surveys have been made to outline a comprehensive system of irrigation to cover the lands mentioned. These surveys will enable detailed estimates of cost and plans for construction to be made and will furnish data for the segregation of the land. The work done has shown that the principal bodies of land can be covered by four canal systems and one ditch, as follows:

In Yellowstone Valley the most important body of land lies between Huntley and Bull Mountain station, on the Northern Pacific Railway, and comprises about 34,500 acres. The Huntley canal line as surveyed is about 40 miles long and can be cheaply constructed after the first 2 miles or so, which lie along the Huntley Bluffs. The difficult part of the line has been covered by plane-table sheets on a scale of 100 feet to 1 inch, and the remainder, being in smooth country, has been staked out and traversed and the slopes taken by stadia readings.

A few miles below the end of the Huntley canal line the diversion point of the Waco ditch was selected. The Huntley canal could not easily be continued on account of the Bull Mountain Bluffs. The Waco ditch is about 19 miles long and will not require any difficult construction work; it will cover about 5,000 acres of very good land. The land lies in a narrow strip between the river and the bluffs, the widest portion being opposite Custer station.

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[a] From report by Robert S. Stockton.

Below the mouth of the Bighorn there is a fine body of land extending from Meyers station, on the Northern Pacific Railway, to within about 6 miles of Forsyth. The largest part of this land lies in the neighborhood of Sanders station and is known as the Sanders Flat. A canal line was surveyed to cover Sanders Flat and the adjoining lands along the Yellowstone; this line covers about 20,000 acres, of which about 6,000 acres are off the reservation. In order to cover so much ground, water must be diverted from Bighorn River about 4 miles above its junction with the Yellowstone, or from the Yellowstone itself about 3 miles above the junction. A line at this elevation covers the land, but entails about 7 miles of difficult construction where the bluffs approach close to the river, the railroad having already taken the best place for its right of way.

The difficult portion of this line along the bluffs has been covered by plane-table topography, from which it is expected to work out the best location and estimate the cost. The choice of the diversion site will depend somewhat on relative cost, but mainly on the water supply.

All of the lands in Yellowstone Valley are traversed by the Northern Pacific Railway. The upper end of the Huntley Flats also is crossed by the Burlington and Missouri River Railway. These facts are material in considering the value of the lands and the cost of construction work.

The surveys show that the lands along the west side of Bighorn River may be watered by means of two canal systems. The Fort Custer canal is surveyed to take water from the Bighorn near the mouth of Two Leggin Creek. This point is about 10 miles above the Burlington and Missouri River Railway crossing at Old Fort Custer, and is at the upper end of the long strip of flat valley land extending nearly to the junction. By means of drops in the line at suitable intervals the Fort Custer canal line is kept close to the edge of the hills without climbing into them, as this would increase the cost far beyond any benefit to be derived. There are probably 30,000 acres to be irrigated by this canal. The line as surveyed would be approximately 45 miles long.

The Bighorn high line has been planned to cover the high-bench land extending from near the mouth of Bighorn Canyon to Two Leggin Creek and beyond, but from Two Leggin Creek on the bench lies back from the river, leaving the flat valley land, which is to be covered by the Fort Custer line. The Bighorn high line as surveyed gradually mounts the divide until, in the vicinity of Toluca, where the Cody branch leaves the Burlington and Missouri Railway, it is possible to cut through and deliver water to lands along Fly Creek, on the Yellowstone slope. By continuing the line on past Peritsa station the bench lands above the Fort Custer line are covered. Under the Bighorn high line and its branches there are possibly 65,000 to 75,000 acres of irrigable land.

CONDITIONS.

The preliminary surveys for the above-mentioned canal lines are just being completed and no office work has been done yet, so that a statement of costs can not be made and the amount of land under each canal given is only approximate. It may be said in general, however, that the Huntley canal line and the Fort Custer canal line can be built at a moderate cost, and are, as far as the engineering features are concerned, suitable for immediate construction. Waco ditch is probably in the same class, and its construction will probably be taken up with the ones previously mentioned.

The Sanders and Bighorn high lines both entail some very expensive construction work, and in the case of the high line additional legislation would be necessary to open the Crow lands, without which it could not be made to pay. The present boundaries of the ceded strip leave a large portion of the lands under the high line in the diminished reservation and also exclude about 10,000 acres from the lands under the Fort Custer canal. The Fort Custer canal will be ready for construction as soon as this body of 10,000 acres of land can be ceded, or some arrangement perfected whereby it can be made to bear a share of the costs. There are some borings to be made along the canal lines and at the diversion sites. This work will probably be undertaken early in the spring.

LANDS.

By act of Congress approved April 27, 1904, the Crow Indians ceded a strip of land in the northern part of their reservation to the United States subject to certain conditions, including the payment of $1,150,000 for the benefit of the Indians and the surveying of the lands. The Indians on the ceded strip are to have a reasonable time within which to elect whether to remain there or to have their improvements appraised and sold and to remove to the diminished reservation. After the completion of allotments to the Indians the residue of the ceded lands is to be subject to withdrawal and disposition under the reclamation act, provided, however, that if the lands withdrawn under the reclamation act are not disposed of within five years all of the lands are to be disposed of as other lands provided for in the act. In addition to the cost of reclamation the price of these lands is to be $4 per acre when entered under the homestead laws, to be paid as follows: One dollar per acre when entry is made and the remainder in four equal annual installments, the first to be paid at the end of the second year.

POWER DEVELOPMENT.

On the Huntley, Sanders, and Fort Custer canal lines are drops of from 12 to 50 feet, some of which at least could be utilized for the development of power. If the Bighorn high line is built it will involve the construction of a dam at the mouth of the Bighorn Canyon, which will probably reach to 100 or 120 feet above high-water mark. The amount of water passing this dam must always be sufficient to supply the Bighorn Indian ditch and the Fort Custer canal, each of which covers about 30,000 acres. Surveys have been made which show that all the power developed can be used to pump water on to lands above the canals, but the details have not been worked out, and, as the lift required is in most cases rather high, it may not be feasible to do much in this line, although there is little doubt that the power will eventually be used in some way.

WATER SUPPLY.

On starting work on the Crow Reservation gaging stations were established on Yellowstone River at Billings and on Bighorn River at Fort Custer. The gages have been read regularly and their readings, together with the discharge measurements taken, will help to determine the available water supply. At present there is a large surplus in both rivers even at low water, and if all the canals contemplated in this vicinity are constructed there would still be an ample supply without storage. But with the construction of other projects in Montana and Wyoming these conditions will be changed and questions of priority and storage will have to be adjusted. During the summer of 1904 the discharge of the Yellowstone at Billings varied from a maximum of over 30,000 second-feet to a minimum of about 4,000 second-feet in October, and the discharge of the Bighorn varied from over 17,000 to about 1,500 second-feet.

From the preceding statements it will be seen that there are about 70,000 acres of land that can be readily irrigated, with the possibility of increasing this to perhaps 160,000 acres. Uncultivated land with a good water right is being sold at $35 per acre in the neighborhood of Billings, indicating that the project might stand a total of $35 an acre if necessary.

The soil along the rivers is mostly heavy clay, suitable for alfalfa and grain. On the higher slopes there are clay loams, silt loams, and fine sandy loams suitable for potatoes and varied crops. Alfalfa does still better on the lighter soils. Apples and small fruits can be raised on these lands. The soils are similar and contain some alkali. The heavy clays along the river will have to be well drained and properly farmed in order to prevent them from becoming impregnated with alkali.

The reservation has a fine climate and good railroad connections and the lands under the project should prove most desirable to home seekers.

MADISON RIVER RECONNAISSANCE.

A reconnaissance was made, under direction of S. B. Robbins, by F. F. Prendergast, assistant engineer, to determine the possibility of diverting the waters of Madison River into a canal running along the left or west bank of that stream and continuing northward across Jefferson River and in a general way parallel with Missouri River, across Winston Pass into the Prickly Pear Valley near Helena. The controlling point is the altitude of Winston Pass, 4,350 feet. In order to surmount this pass the diversion point must be above the mouth of Hot Springs Creek. The elevation here is about 4,500 feet.

For diverting the water there will be required a masonry weir about 300 feet long and 10 feet high. From the weir the canal must run along the base of steep rock slopes for about 8 miles, the country gradually opening out and permitting more earth bank. The distance to Jefferson River is about 35 miles and the grade elevation at this point is 4,455 feet. The water surface of Jefferson River is approximately 4,180 feet, so that to cross the valley it will be necessary to put in an inverted siphon about 2 miles long, with an approximate head of 240 feet. Beyond Jefferson Valley the grade is 4,415 feet and then 11 miles of steep hillside country must be crossed. The canal line thence continues 23 miles through relatively easy country to Radersburg. Up to this point the capacity of the canal has been estimated at 1,000 second-feet. Beyond this the proposed capacity is 500 second-feet. It is proposed to irrigate about 50,000 acres up to this point, and to carry 500 second-feet into the Prickly Pear Valley for the irrigation of about 50,000 acres of land.

Leaving Radersburg at grade of 4,371 feet the smaller canal reaches Winston Pass at a grade of 4,331 feet and passes through a 20-foot cut for a distance of about 2,000 feet.

Besides the engineering difficulties, there are serious question connected with the water supply. Power plants already established on Missouri River utilize the entire stream flow during part of the year, and the diversion of 1,000 second-feet from Madison River would probably necessitate shutting down or reducing the effectiveness of these plants during a part of the year.

OPERATIONS IN NEBRASKA.

By JOHN E. FIELD.

NORTH PLATTE RIVER PROJECTS.

Prior to 1904 investigations had been begun on the North Platte River projects and considerable progress looking to the development of the valley of the North Platte had been made. As the work proceeded it became apparent that storage must be secured if any considerable area of land was to be reclaimed. The flow of the North Platte at the Wyoming-Nebraska line was found to be so small that there was already a scarcity of water when the river was low.

With these conditions in mind, the securing of adequate storage was of the utmost importance. Investigations of the Sweetwater reservoir had proved its impracticability on account of the shortage of water. The Pathfinder reservoir site, however, lying in the valley of the North Platte at its junction with the Sweetwater, was found to be adequate (see Pl. XXX). Surveys had been made of the valley and of the dam site, both being found to be exceptionally favorable. As reported heretofore, the capacity will exceed 1,000,000 acre-feet, and the cost will be scarcely more than $1 per acre-foot, the reservoir being capable of controlling all the surplus flow of the river for the entire year, unless the discharge be exceptionally large.

The dam is located in a solid-rock box canyon 3 miles below the mouth of the Sweetwater. At the point selected for the dam the canyon varies in width from 60 feet at the bottom to 160 feet at the top; its extreme height from bed rock is about 200 feet. Diamond-drill borings made in 1903 show perfect foundations of granite.

With the necessary storage provided, the next step necessary was the finding of land on which water could be used, and, contrary to expectations and popular belief, this proved to be far the most serious and difficult problem. The fall of the North Platte is from 4 to 6 feet per mile. It flows in Wyoming through a channel bordered by very narrow and small areas of bottom land from which the hills rise rapidly away from the river at a height of from 100 to 500 feet, necessitating long and expensive canals.

SWEETWATER VALLEY CANALS.

Immediately below the Devils Gate on the Sweetwater there is a broad valley lying at an elevation that can be easily reached by canals heading at the Devils Gate. On account of the great demand for stock feed of all kinds for winter use and the high prices which such products command, it was deemed advisable to secure, if possible, the irrigation of this valley.

Though there was an insufficient water supply to justify the building of the Sweetwater dam and the creation of so large a reservoir, the records of the flow in the Sweetwater showed there was sufficient water if stored to reclaim all the land in the valley below the dam. About 60,000 acre-feet of water passes through the Devils Gate, and if stored when not needed for immediate use would be sufficient to irrigate at least 20,000 acres. It was hoped this amount of irrigable land could be found, and a classification of the land was made, a canal line was run on both sides of the river, and the cost estimated. The results were as follows:

Cost of irrigation in Sweetwater Valley.

Amount of land under canals	acres	28,000
Amount of irrigable land	do	8,000
Cost of canals		$250,000
Cost per acre, at least		$30

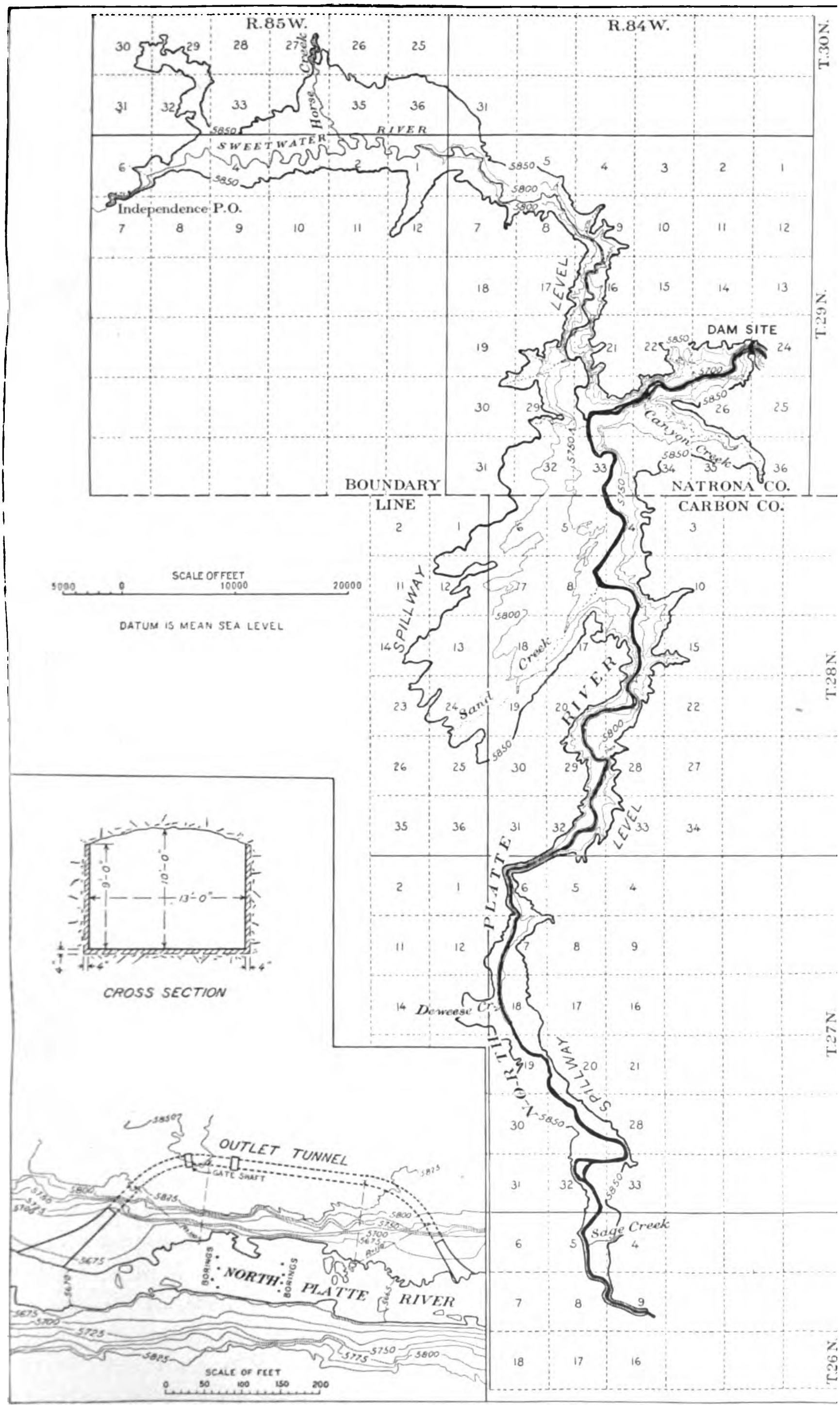
On account of the high expense the district engineer recommended that the project be abandoned. In this opinion the board of consulting engineers concurred, in May, 1904, since which time no work has been done either on the reservoir or lands. The recommendations of the board were as follows:

> That the further examination of the project described herein be abandoned, and that the lands segregated pending examination be restored to entry, the reasons for such action being:
>
> (1) The cost of the works, which would be over $250,000.
>
> (2) The small area of land reclaimed, a little over 10,000 acres, which would make the cost of reclamation nearly $30 per acre when the cost of laterals is added.
>
> (3) The small yield per acre, which it is believed does not justify the expenditure per acre.
>
> (4) The large amount of land held in private ownership, the owners of which would probably be unwilling to cooperate with the Government.
>
> (5) The probability that the enterprise is more within the range of private than of national enterprise, if, notwithstanding items 2 and 3, it should be deemed feasible.

ALCOVA-CASPER CANAL.

In a further effort to secure land for reclamation as high up on the stream as possible, a line was run from Alcova, about 8 miles below the Pathfinder reservoir, to a point about 8 miles north of Casper.

The project contemplated a 50-foot dam at Alcova, and the canal was to be extended indefinitely eastward to cover lands on the north side of the divide between North Platte River and the tributaries of the Missouri, as well as lands in the valley of the North Platte.



MAP OF PATHFINDER RESERVOIR AND DAM SITE, NORTH PLATTE PROJECT, WYOMING.

The canal to the point south of Casper would have a length of about 80 miles. It would traverse country in which construction would be very expensive and maintenance uncertain and costly. For miles it would skirt shale and gypsum hills, cross deep arroyos and penetrate narrow adobe or shale ridges. The results of the surveys were as follows:

Amount of land under canal	acres	40,000
Amount of irrigable land	do	30,000
Cost per acre, more than		$60

Upon the recommendation of the district engineer the board of consulting engineers ordered that nothing more be done on this project.

CASPER-DOUGLAS CANAL.

SOUTH SIDE.

The Casper-Douglas canal extends from a point about 8 miles above Casper, on the south side of the river, to near Inez. A preliminary survey to ascertain the probable amount of land that could be covered was made in June and July, 1904.

A canal 60 miles in length would cover all the irrigable land on the first bench above the river, the greater acreage being in the small valleys on the tributary streams. The area covered would be about 25,000 acres. It is possible to enlarge the project considerably by extending it to the Fetterman Flats and by irrigating the lands at Careyhurst. The latter now have a sufficient supply from Boxelder Creek, but if all the land under the proposed canal were irrigated from Boxelder Creek, the released water could be used on land higher up on the Boxelder and an equal amount of land now desert reclaimed.

Nearly all the land is in private ownership, and much is held in large tracts, notably the Careyhurst lands and the Fetterman Flats. It is probable that a cooperative plan can be worked out by the owners of the land, or, in the hands of a water-users' association the project could be made feasible by bringing all the private lands into the project.

NORTH SIDE.

The north-side canal was surveyed late in the fall of 1903 by A. J. Parshall. Lines had been run previously by Elwood Mead and W. D. Pease. Wooden flumes and works of cheaper and less permanent character than would be put in by the Government were contemplated. The area covered is in excess of 25,000 acres, much of which, however, is rough and not irrigable. Probably there are between 15,000 and 20,000 acres of good land.

Most of the land under this canal is in private ownership. Further examination and surveys are intended.

GOSHEN HOLE CANAL.

At Goshen Hole the entire season of 1903 was consumed in making preliminary locations and gathering data sufficient to make preliminary estimates.

The canal would be about 140 miles in length, of which about 6 miles would be tunnel. Numerous reservoir sites which could be easily developed exist along the line, and would be of great utility to the system. There are estimated to be 150,000 acres of irrigable land under the canal, probably 10,000 more which can be reached by pumping, and 5,000 more which lie under a short canal on the north side of the river at Guernsey. The lift would not be great and the power could be economically generated at the diversion dam at Guernsey. This diversion dam will necessarily be rather expensive, being 125 feet long at low water and about 1,400 feet long at its crest.

The land in Goshen Hole is of good quality, though somewhat rolling and in places broken. The nature of the foundation for the diversion dam has not been determined. On October 1 borings with the diamond drill were begun, but have not yet resulted in anything definite. Topographic surveys of the upper 6 miles of the canal were made in the spring of 1904, and a report on the soil will be made by Mr. Thomas H. Means shortly.

With this additional information, the estimates will be revised during the coming winter. The new information indicates more favorable conditions than those assumed for the first estimate. It is possible to irrigate much of the 150,000 acres under the Goshen Hole canal by means of a lower lying canal—the Fort Laramie. This would materially reduce the size and cost of the main canal and of the lateral system.

FORT LARAMIE CANAL.

During the past summer a preliminary line was run on the south side of North Platte River in Laramie County, Wyo., beginning at a point about 8 miles west of old Fort Laramie, at the same point where the proposed Interstate canal will head, but on the opposite side of the river.

The land under the Fort Laramie canal, as shown by the preliminary survey, embraces nearly 50,000 acres, about equally divided between Wyoming and Nebraska. The line as run was about 120 miles in length and ended at a point about 5 miles east of Gering, Nebr. The land covered, especially that in Nebraska, is of the best quality.

With reference to this canal two propositions present themselves—whether it would be more economical to build the Goshen Hole canal with a capacity sufficient to irrigate the 50,000 acres under the Fort Laramie canal or whether it would be more economical to build the Goshen Hole canal smaller and to irrigate the 50,000 acres from a lower line canal, such as the Fort Laramie. One of these two courses will probably be adopted. If, however, the cost of construction of the Goshen Hole canal prove prohibitive, the information at hand seems to indicate that the Fort Laramie canal can be constructed with a reasonable expenditure.

PATHFINDER RESERVOIR.

The records of the flow of water in North Platte River, as shown by gaging station records at Guernsey, Mitchell, Bridgeport, and North Platte and the records of the office of the State engineer of Nebraska show that during the month of August of each year a scarcity of water exists for canals now in operation and for lands now being cultivated.

Under the canals now in operation there are considerable tracts of land not in cultivation. These lands are being gradually put into crop, increasing the demand upon the canal for water from the river.

Efforts are now being made to extend a number of existing canals and to bring additional land under irrigation. If this is done, the shortage of water will be still more marked. The conclusion is, therefore, that no considerable additional area which is not dependent upon stored water can be reclaimed.

There are in the State of Nebraska alone about 107,000 acres in cultivation in North Platte Valley, while the records at the State line and at Guernsey show that the low-water flow for almost every year is as low as 400 second-feet. The period when the water supply at the State line is less than 1,000 second-feet extends approximately from the middle of July to the end of the irrigating season, and were it not for the considerable return seepage and underground waters reaching the river there would be a serious shortage after the middle of July. It is almost certain, therefore, that in the extension of existing canals any assurance of a sufficient supply of water must come from storage.

An examination of the table showing the lands under the interstate canal indicates that a minimum of 100,000 and perhaps 160,000 acres will be reclaimed by it, all dependent for their water supply on the Pathfinder reservoir. In addition to this it is probable that almost all existing canals will desire water from the Pathfinder reservoir if it can be obtained. Such a demand is not apparent at present, but with a change to crops requiring later water and crops maturing later the demand for reservoir water will constantly increase.

For these reasons preliminary work on the Pathfinder reservoir has been begun. Plans for the outlet tunnel and gates have been approved, and it is probable that contracts will be let for them and for the temporary power plant during the coming winter.

The development of power at the dam site is necessary in the construction of the dam. The supply of wood for fuel is very small. The available coal supply is poor and requires a haul by wagon of more than 25 miles. In either case the development of power would be very expensive.

By the construction of a temporary power plant in the canyon, about a mile below the dam, sufficient power can be generated for pumps, derricks, crushers, mills, lighting, and other purposes. By such an electrical development night work will be possible.

Table showing lands to be irrigated from stored water from the Pathfinder reservoir.

Canal.	Maximum.	Probable.	Minimum.
	Acres.	*Acres.*	*Acres.*
Casper-Douglas (south side)	20,000	20,000	....
Douglas (north side)	15,000	15,000	....
Goshen Hole	100,000	100,000	....
Fort Laramie	50,000	50,000	50,000
Interstate	238,000	160,000	110,000
Canals now in operation[a]	107,000	107,000	....
Total	530,000	352,000	160,000

[a] To be supplied for late irrigations if there is a surplus of stored water after other lands are supplied.

INTERSTATE CANAL.

The area under the interstate canal may amount to 238,000 acres, but, as stated before, much of this land can be served by other canals. Dividing it according to such service we have the following tabulation:

Table showing lands under interstate canal classified by their positions under other canals.

[In acres.]

Lands under	Minimum.	Probable.	Maximum.
Interstate canal only:	*Acres.*	*Acres.*	*Acres.*
Government	80,000	80,000	100,000
Private	10,000	20,000	30,000
Whalen Falls canal:			
Carey Act	10,000	10,000	14,000
Private	10,000	10,000	14,000
Farmers' canal			
Controlled by sugar company		....	30,000
Private		30,000	30,000
Other canals		10,000	20,000
Total	110,000	160,000	238,000

Seventy per cent of these lands are first class, and the remaining 30 per cent are almost entirely second class. Practically no third-class land is embraced in the 110,000 acres estimated, all high, worthless, and badly broken land having been excluded as far as possible.

Whalen Falls canal was built and promoted primarily to irrigate about 14,000 acres of land, mostly on the eastern side of Rawhide Creek, under the Carey act; and, secondarily, to irrigate about an equal amount in private ownership, nearly all of which lies west of Rawhide Creek. The canal has been constructed in a temporary manner as far as Rawhide. No diversion dam has been built and the headworks are of the most temporary character. Negotiations have been in progress for some time looking to the practical abandonment of the project under the Carey act and to its completion under the reclamation law.

The construction of the Farmers' canal was begun many years ago. It was completed to Spotted Tail Creek, just north of Mitchell, Nebr. The canal heads just east of the Nebraska-Wyoming State line, and, as completed, is about 20 miles in length. Its original capacity was probably 600 second-feet, but its present capacity is probably not more than one-third of that amount.

About 1893 financial difficulties overtook the company and construction was suspended. It has not been resumed, and, until recently, the abandonment of the extension was generally conceded. Some months ago a petition was circulated among the owners of land under the uncompleted portion of the Farmers' canal, asking the Government to construct the interstate canal of sufficient capacity to irrigate these lands. The amount of land represented by these petitioners was about 30,000 acres.

The headworks of the interstate canal will be a diversion dam from 6 to 10 feet above the bed of the river and from 300 to 350 feet in length. Its exact location has not yet been determined. Borings will be made in the near future to determine this point.

The first 20 miles of canal are in fairly difficult country. After these are passed little difficult country is encountered, the most serious being for about 1 mile through sand hills. The greatest obstacle there, however, is not in construction, but in loss by seepage. For almost the entire distance the excavation will be in earth. Little side-hill work will be encountered, and the cost should be rather low for so large a canal; also there are numerous reservoir sites along the line of canal, which will simplify the matter of seepage and the maximum demand upon the canal during the latter part of June and early part of July.

RECONNAISSANCE ON NIOBRARA AND SNAKE RIVERS.[a]

PURPOSE AND EXTENT OF THE SURVEY.

The purpose of the Niobrara and Snake rivers reconnaissance was to determine approximately the fall of the rivers, to obtain measurements of the flow of these streams and of their principal tributaries, and to note and examine any reclamation project that might present itself.

The country traversed embraced the lands lying contiguous to Niobrara River between Tps. 30 to 34, Rs. 24 to 45, inclusive; those near Snake River, in Tps. 32 and 31, R. 30, and in T. 30, Rs. 31 and 32; and a territory known as the "lake country," in Tps. 30, 31, 32, 33, and 34, Rs. 23, 24, 25, 26, and 27. A total distance of 351.6 miles, as registered by an odometer, was traversed.

NIOBRARA RIVER.

DRAINAGE AREA.

The drainage area of the river consists largely of sand hills, which fact no doubt is responsible for the marked constancy of flow of this stream and its tributaries, since a large per cent of the water precipitated into its basin is immediately absorbed by the sand, passing downward to appear again in the form of springs.

These sand hills cover the larger part of Cherry, Sheridan, Grant, Hooker, Thomas, McPherson, Blaine, Loup, Brown, and Rock counties, and are of little value except for range land, from 10 to 50 acres being required to pasture one cow. Here and there are found valleys, or "hay flats," usually running east and west, on which are cut quantities of wild hay. The soil is not susceptible of cultivation, because as soon as the ground is broken it begins to "blow." Often over several acres the sand is blown out to the depth of 20 feet.

Throughout the entire area traversed these sand hills are the characteristic feature. Sometimes they border the banks of the stream and sometimes recede several miles, leaving between them and the river rolling strips where the soil is much firmer and is susceptible of a high degree of cultivation. The rainfall, however, is not sufficient to insure good crops, and in nearly every case the rolling character of the land would prevent irrigation, even were it possible to get water onto the land. On the upper Niobrara, on the north side, from about R. 37 W., these areas of tillable land are of very large extent, beginning several miles back from and extending to the river.

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[a] From report by J. C. Stevens.

THE RIVER BED.

The Niobrara River throughout almost its entire length has cut a canyon from 20 to 400 feet deep through the magnesia or "chalk rock" strata, characteristic of this part of the country, which makes a firm fertile soil where it has not been encroached upon by the sand hills. This "chalk rock" resembles limestone and is often used for building purposes. Buildings made of this material fifteen years ago have been examined and the stone found to be in a good state of preservation, showing scarcely any signs of weathering. It is not noticeably affected by frosts.

IRRIGABLE LANDS.

The only lands within the limits of this survey practically susceptible of irrigation are found in narrow strips along the banks in the bottom of its canyons. These seldom contain more than 100 acres, and while the problem of their irrigation is very simple, yet little attempt has been made to reclaim them. On the upper Niobrara, however, from Hay Springs westward, a number of ditches are in successful operation.

The only lands outside of the canyon which were level enough to irrigate were a series of flats of limited extent, undoubtedly the former bed of the river, but now from 150 to 250 feet above the water surface.

Boiling Springs flat.—This tract lies on the south side of the river in T. 33, R. 34, and contains about 7,000 acres. Its elevation above the bed of the river, as determined by aneroid, is 200 feet. The discharge of the river near this point was 221 second-feet on August 18, 1904. The soil is sandy, but very fertile, and contains no injurious salts. The rainfall, however, is insufficient to insure crops.

Conley flat.—This flat lies on the north side of the river in Ts. 33 and 34, R. 35, between Niobrara River and Bear Creek, its lower end being opposite the upper end of Boiling Springs flat. It contains about 4,000 acres of level land, and is similar in all respects to Boiling Springs flat.

Missouri flat.—Though hardly worth the name of a flat, having been encroached upon by sand hills, still this may be classified as such. It lies on the south side of the river in T. 33, R. 36, its lower end opposite the upper end of Conley flat, and contains about 3,000 acres.

Summary.—In the three flats combined there are about 15,000 acres of level land, but they are so high above the bed of the river that their irrigation from it is out of the question. The land is all held in comparatively large tracts by a few parties, and is valued from $1 to $3 per acre.

DISCHARGE OF NIOBRARA RIVER.

Below is given a table showing the discharge of the river and of all its tributaries at various points. The total gain between successive gaging sections and the gain per mile is shown in the table on page 329. Points where measurements were made are given in order in the table, beginning at the west. The river has been divided into sections, at the extremities of which measurements were made.

The "inflow" into any section, therefore, consists of the discharge of the Niobrara at its upper end and of all tributaries throughout the section. The "outflow" represents the discharge of the river at the lower end of the section and the diversions, if any.

The time of making these measurements extended over about fourteen days, so that not very much dependence should be placed on the results given in the last two columns. It is seen that the increase is from about 1½ to 4 second-feet per mile, except for a 6-mile section in T. 33, Rs. 37 and 38, where the increase was 10.5 second-feet per mile. Part of this was undoubtedly due to change in the stage of the river, since about fifteen hours elapsed between gagings; yet, while there are no tributaries, copious springs abound in this locality.

Discharge measurements in Niobrara River basin in 1904.

Stream.	Location.			Date.	Discharge in second-feet.	Remarks.
	Sec.	*T.*	*R.*			
Pine Creek	22	30	44	Aug. 23	12.8	At bridge, near mouth.
Niobrara River	18	30	43	....do...	27.0	
Deer Creek	15	30	43	....do...	7.3	One-fourth mile above mouth.
Rush Creek	32	31	42	Aug. 22	.6	
Niobrara River	24	31	42	....do...	54.0	At bridge due south of Gordon.
Do	35	33	38	Aug. 21	117.0	At Sanborn's bridge.
Do	27	33	37	Aug. 20	180.0	At Rockford bridge.
Do	12	33	36	....do...	200.0	At Crane's bridge.
Bear Creek	32	34	34	Aug. 19	2.0	One-fourth mile above mouth.
Niobrara River	10	33	34	Aug. 18	221.0	At Boiling Spring bridge.
Snake River	2	30	32	Aug. 17	194.0	At Government bridge.
Do	10	30	31	Aug. 16	204.0	At private bridge on Tait's ranch.
Boardmans Creek	12	30	31	....do...	7.3	One-fourth mile above mouth.
Snake River	15	32	30	....do...	279.0	By wading 2 miles above mouth.
Niobrara River	9	33	27	Aug. 11	584.0	At Valentine gaging station.
Do	9	33	27	Aug. 24	638.0	Do.
Minnechaduza River	36	34	28	....do...	21.0	Above backwater from dam.
Niobrara River	27	34	26	Aug. 14	679.0	At Berry's bridge.
Do	31	33	23	Aug. 13	752.0	Bridge 6 miles south of Norden.
Fairfield Creek	31	33	23	....do...	21.5	One-half mile above mouth.
Plum Creek	8	31	23	....do...	80.0	Bridge 7 miles north of Johnstown.

Table showing increase in discharge of Niobrara River.

Section limits.			Inflow.	Outflow.	Gain in second feet.	
Upper.	Lower.	Length.			Total.	Per mile.
Sec. T. R.	*Sec. T. R.*	*Miles.*				
18 30 43	24 31 42	13	Niobrara 27.0	Niobrara 54	19	1.5
			Deer Creek 7.3			
			Rush Creek 6			
			Total 35.0			
24 31 42	35 33 38	28	Niobrara 54	Niobrara 117	63	2.3
35 33 38	27 33 37	6	Niobrara 117	Niobrara 180	63	10.5
27 33 37	12 33 36	9	Niobrara 180	Niobrara 200	20	2.2
12 33 36	10 33 34	12	Niobrara 200	Niobrara 221	19	1.6
			Bear Creek 2			
			Total 202			
10 33 34	9 33 27	46	Niobrara 221	Niobrara 638	133	2.9
			Snake 279			
			Gordon (est.) 5			
			Total 505			
9 33 27	27 34 26	8	Niobrara 638	Niobrara 679	20	2.5
			Minnechaduza 21			
			Total 659			
27 34 26	31 33 23	19	Niobrara 679	Niobrara 752	73	3.8

FALL OF NIOBRARA RIVER.

The Niobrara has a fall of over 9 feet per mile through the State, as determined by railroad surveys of the water surface at Marsland and Niobrara, the latter situated at the mouth of Niobrara River. The distance between these two points by water is 300 miles, and difference in elevation 2,767 feet. At Marsland the elevation of the water surface, as determined by the Burlington and Missouri River Railroad, is 4,112 feet, and at Valentine the elevation of the water surface, as determined by the Chicago and Northwestern Railroad, is 2,390 feet; the distance between the two places is 160 miles, thus giving a fall of 12 feet per mile. Below Valentine the river gradually spreads out over its sandy bed, and the canyon in which it runs is not nearly so deep or narrow as above this point.

Below is given a table of elevations of various points on the river, as determined by aneroid barometer. They are, of course, only approximate. The first column gives the station numbers corresponding to those of the original survey notes.

Elevations along Niobrara River in Nebraska.

Station.	Location.			Elevation.	Difference in feet.	Distance in miles.	Fall per mile in feet.
	Sec.	*T.*	*R.*				
8	31	33	23	2,150	....	....	....
12	21	34	26	2,370	220	19	11
1	4	33	27	2,470	100	9	11
21	10	33	34	2,900	430	46	9
32	12	33	36	3,020	121	12	10
34	27	33	37	3,100	80	9	9
35	35	33	38	3,150	50	6	9
37	24	31	42	3,420	270	28	10
40	22	30	44	3,570	150	17	9

PRESENT USES OF NIOBRARA RIVER AND ITS TRIBUTARIES.

Aside from a limited number of irrigation ditches on the upper Niobrara the river is put to no practical use whatever. A few mills are found on some of its tributaries, and a small reservoir and power plant have been constructed on Minnechaduza Creek, at Valentine, from which power is furnished to a large flouring mill and to the city for its waterworks system and lighting plant. About 125 horsepower is developed with a 30-foot head. Surveys have been made for a proposed power plant on the Niobrara near Valentine whereby, with a 50-foot dam having a 500-foot crest, about 4,000 continuous horsepower can be developed at a cost of from $40 to $50 per horsepower.

SNAKE RIVER.

This river is a tributary of the Niobrara, emptying into it in sec. 2, T. 32, R. 30, and is in nearly all respects its counterpart. The canyon near its mouth is about 350 feet deep, having been cut by the stream through the magnesia or chalk-rock formations characteristic of the country.

DEVELOPMENTS.

There are no irrigable lands contiguous to the lower Snake (nothing but sand hills), so that its development in this connection is out of the question. Power could be developed at very little expense, but there seems to be no practical use for it.

FALL AND DISCHARGE.

The total fall of the Snake from sec. 15, T. 32, R. 30, to sec. 10, T. 30, R. 31, a distance of 60 miles, was found to be 370 feet. The total height of the series of falls is about 50 feet, thus leaving a fall per mile of 20 feet. From sec. 10, T. 30, R. 31 to sec. 2, T. 30, R. 32, a distance of 5 miles, the total fall was found to be about 70 feet, giving a fall of 14 feet per mile. The discharge of the stream was measured at three different points. The results may be found in the preceding table.

THE LAKE COUNTRY.

This territory embraces a strip of country in Cherry County extending for 10 or 15 miles on both sides of the seventh standard parallel. The lakes themselves are seldom more than swamps, though Reddeer Lake, Moon Lake, Clear Lake, and Stephenson Lake may be mentioned as among those having well-defined banks, and may be considered simply as valleys or hay flats whose bottoms are below the general water table of the country.

These lakes are said to have periodic rises, and in order to determine the extent of these fluctuations a gage rod was established on Reddeer Lake, in sec. 15, T. 30, R. 27, and an observer employed to observe weekly gage heights.

OPERATIONS IN NEVADA.

By L. H. Taylor.

TRUCKEE-CARSON PROJECT.

SUMMARY OF WORK DONE.

During 1904 the surveys and construction work begun under the direction of L. H. Taylor, engineer, in 1902 and 1903, were continued in the basins of the Truckee and Carson rivers. Following is a brief summary of the work done:

1. In Carson Sink Valley 314 square miles of irrigable land were mapped with plane table on a scale of 4 inches to 1 mile, with 5-foot contour interval.
2. In Churchill and Dayton valleys 97 square miles were mapped on a scale of 4 inches to 1 mile, with 5-foot contour interval.
3. In Upper Carson Valley 67 square miles were mapped, in cooperation with the State engineer, on a scale of 4 inches to 1 mile, with contour intervals of 5 and 10 feet.
4. In the vicinity of Wadsworth and Pyramid Lake 39 square miles were mapped on a scale of 4 inches to 1 mile, with 5- and 10-foot contour intervals.
5. In Lovelock Valley 38 square miles were mapped on a scale of 4 inches to 1 mile, with 5-foot contour interval.
6. There were located 37 miles of main canals for delivering water to lands in Carson Sink Valley, from a point on Carson River about 4 miles below the lower Carson reservoir, and preliminary surveys for about 60 miles of extensions of these were made.
7. There were located 250 miles of lateral irrigation and waste ditches in the Carson Sink Valley.
8. For the regulation of the flood waters of Carson River and the control and disposal of waste water in Carson Sink Valley about 24 miles of main canal were located, and preliminary surveys, with topographic maps on a scale of 200 feet to 1 inch and 1 and 2 foot contour intervals, were made.
9. Preliminary survey and plotting on scale of 100 feet to 1 inch, with 5-foot contour intervals, was made of Alkali Flat reservoir supply and outlet canals.

10. In retracing township and section lines and restoring lost and obliterated corners 1,000 miles were run.

11. Portions of T. 19 N., R. 27 E., Ts. 18 and 19 N., R. 28 E., and T. 18 N., R. 29 E., Mount Diablo base and meridian, were subdivided into farm units and all the corners of such units were set.

12. Diamond drilling for the examination of bed rock at Lower Carson dam site was completed.

13. Construction of divisions 1 and 2 of the main canal and structures of the Truckee-Carson project, under contract of C. A. Warren & Co., begun October 2, 1903, is about 92 per cent completed.

14. Construction of division 3 of the main canal and structures, Truckee-Carson project, under contract of E. B. & A. L. Stone Company, begun September 11, 1903, was finished September 30, 1904.

15. Excavation of 37 miles of main distributing canals under contract of the Pacific Coast Construction Company was begun in September, 1904, and is about one-third completed.

16. Construction of diversion dam and headworks of the main distributing canals—in Carson River—has been commenced under contract of R. C. Mattingly.

17. Construction of highway bridges under contract of Clarence W. Swain and of falls, lateral head gates, culverts, and spillways for main distributing canals, is under way.

WATER SUPPLY.

The Truckee-Carson project (Pl. XXXI) contemplates the utilization of the waters of Truckee and Carson rivers for irrigation. Each of these rivers has its collecting basin on the eastern slope of the high Sierra Nevada, mostly in California, in a forest-clad region, which ranges in elevation from 5,000 to over 11,000 feet above sea level, and in which the precipitation, mainly in the form of snow, is heavy.

Upper Truckee River has a general northerly course and flows into Lake Tahoe, which has an elevation of 6,225 feet above sea level, and an area of 193 square miles. From the lake the river continues in a northerly direction for a short distance, receiving a number of tributaries, after which it turns eastward. After passing Verdi the river, entering what has been called the lower portion of the Truckee River basin, continues eastward for 45 miles, passing through Reno Valley and Lower Truckee Canyon to Wadsworth. It then turns northward, and about 20 miles below discharges into Pyramid and Winnemucca lakes.

The east and west branches of Carson River have a general northerly course and, after debouching from the main Sierra Nevada, cross the California-Nevada boundary and unite in Upper Carson Valley, near Genoa, forming Carson River. This stream then flows northeastward for about 80 miles, traversing Upper Carson, Dayton, and Churchill valleys and three intervening canyons to a point in Carson Sink Valley between Leetville and Fallon, where it divides into three branches, one of which discharges into Carson Lake; one, Old River, continues northeastward for a distance of about 18 miles to Carson Sink, and the third, New River, flows eastward into Stillwater Slough and thence northeastward into Carson Sink.

For a number of years systematic measurements of the discharge of both Truckee and Carson Rivers have been carried on at several different points for the purpose of determining the character and quantity of the water supply. The results of these investigations are briefly summarized in the following tables:

Estimated monthly discharge of Truckee River near Vista, Nev.

[Drainage area, 1,519 square miles.]

Month.	Discharge in second-feet.									Total in acre-feet.	Run-off.	
	1890.	1891.	1892.	1899.	1900.	1901.	1902.	1903.	Mean.		Second-feet per square mile.	Depth in inches.
January	......	[a] 700	593	......	547	661	389	653	590	36,280	0.388	0.441
February	......	[a] 650	505	......	428	1,486	598	624	715	39,709	.471	.490
March	......	[a] 650	723	......	857	1,328	589	1,077	871	53,556	.573	.661
April	[b] 4,496	1,523	854	......	755	1,380	1,922	1,537	1,781	105,977	1.172	1.308
May	5,990	2,765	937	......	1,257	2,145	1,610	1,852	2,365	145,418	1.557	1.795
June	4,162	1,905	......	......	709	1,263	1,056	1,020	1,686	100,324	1.110	1.238
July	2,198	945	......	......	110	425	[a] 292	259	705	43,349	.464	.535
August	952	485	......	114	122	315	311	192	356	21,890	.234	.270
September	682	558	......	123	192	329	443	321	378	22,490	.249	.278
October	742	561	......	378	429	477	485	486	508	31,236	.334	.385
November	765	508	......	530	567	557	778	845	649	38,620	.427	.476
December	[a] 750	508	......	456	561	510	[a] 650	569	572	35,170	.376	.433
Total	......	980	......	......	544	906	758	786	931	674,000	.612	8.316

[a] Estimated. [b] April 26-30.

Estimated monthly discharge of Truckee River at Tahoe, Cal.

[Drainage area, 519 square miles.]

Month.	1895.	1896.	1900.	1901.	1902.	1903.	Mean.	Total in acre-feet.	Run-off.	
									Second-feet per square mile.	Depth in inches.
January	....	262	....	102	125	266	189	11,621	0.364	0.420
February	....	290	....	81	73	103	137	7,609	.264	.275
March	....	....	....	30	52	190	91	5,595	.175	.202
April	....	....	....	9	48	18	23	1,369	.044	.049
May	....	....	....	0	97	13	55	3,382	.106	.122
June	....	....	52	30	95	88	54	3,213	.104	.116
July	914	....	214	225	204	205	352	21,644	.678	.782
August	425	....	235	419	406	344	365	22,442	.703	.810
September	374	....	196	326	350	398	329	19,577	.634	.707
October	415	....	159	282	324	374	311	19,123	.599	.691
November	470	....	135	247	346	255	373	12,195	.719	.802
December	250	....	81	111	328	260	206	12,666	.397	.458
Total	....	....	....	155	204	205	207	140,436	.399	5.434

Estimated monthly discharge of Truckee River at Nevada-California State line.

[Drainage area, 955 square miles.]

Month.	Discharge in second-feet.						Total in acre-feet.	Run-off.	
	1899.	1900.	1901.	1902.	1903.	Mean.		Second-feet per square mile.	Depth in inches.
January	....	392	314	322	522	388	23,860	0.406	0.468
February	....	318	1,082	506	463	592	32,880	.620	.646
March	....	797	1,280	402	686	791	48,640	.828	.955
April	....	902	1,476	1,656	1,301	1,334	79,380	1.40	1.56
May	....	1,528	2,478	1,927	1,658	1,898	116,700	1.99	2.29
June	....	950	1,595	1,358	1,148	1,263	75,150	1.32	1.47
July	....	459	686	501	513	540	33,200	.565	.651
August	....	396	486	506	490	470	28,900	.492	.567
September	276	367	472	482	489	417	24,810	.437	.488
October	354	481	470	450	507	472	29,020	.494	.570
November	581	480	469	416	855	560	33,320	.586	.654
December	295	407	445	482	403	406	24,960	.425	.490
The mean	....	623	938	751	753	761	550,800	.797	10.81

Estimated monthly discharge of Carson River at Empire, Nev.

[Drainage area, 894 square miles in 1890, afterwards 988 square miles.]

Month.	Mean discharge in second-feet.							Total in acre-feet.	Run-off.	
	1890.	1895.	1900.	1901.	1902.	1903.	Mean.		Second-feet per square mile.	Depth in inches.
January	....	....	....	115	225	264	201	12,359	0.203	0.234
February	....	....	....	645	280	378	434	24,103	.439	.457
March	....	....	....	634	410	308	448	27,546	.453	.522
April	1,565	....	....	700	618	681	891	53,018	.902	1.006
May	3,475	....	....	1,995	1,041	1,321	1,958	120,393	1.982	2.285
June	3,143	....	....	1,421	1,002	1,411	1,744	103,775	1.765	1.969
July	2,159	802	....	468	170	279	776	47,714	.785	.905
August	756	149	....	126	19	20	214	13,158	.217	.250
September	144	192	....	39	15	15	81	4,820	.082	.091
October	....	154	70	113	54	49	88	5,410	.089	.103
November	....	304	109	197	160	221	198	11,782	.200	.223
December	....	211	93	311	214	203	206	12,666	.208	.240
Total	....	....	....	563	351	429	603	436,744	.610	8.285

Estimated monthly discharge of West Fork of Carson River at Woodfords, Cal.

[Drainage area, 70 square miles.]

Month.	Discharge in second-feet.								Total in acre-feet.	Run-off.	
	1890.	1891.	1892.	1900.	1901.	1902.	1903.	Mean.		Second-feet per square mile.	Depth in inches.
January	....	52	45	......	51	107	49	61	3,751	0.871	1.004
February	....	48	46	......	111	238	63	101	5,609	1.443	1.503
March	....	61	65	......	170	138	64	100	6,149	1.429	1.647
April	284	127	....	......	234	175	174	199	11,841	2.843	3.172
May	657	534	....	......	472	287	389	468	28,776	6.686	7.708
June	614	338	....	......	289	319	353	383	22,790	5.472	6.105
July	380	130	....	......	136	120	106	174	10,699	2.486	2.866
August	135	65	....	......	77	40	42	72	4,427	1.029	1.186
September	75	41	....	......	43	32	30	44	2,618	.629	.702
October	67	48	....	44	49	34	31	46	2,828	.657	.757
November	49	43	....	48	56	46	63	51	3,035	.729	.813
December	53	47	....	53	82	58	66	60	3,689	.857	.988
Total	....	128	....	......	147	132	119	147	106,212	2.094	28.451

Estimated monthly discharge of East Fork of Carson River at Rodenbah's ranch, near Gardnerville, Nev.

[Drainage area, 381 square miles.]

Month.	Discharge in second-feet.							Mean.	Total in acre-feet.	Run-off.	
	1890.	1891.	1892.	1900.	1901.	1902.	1903.			Second feet per square mile.	Depth in inches.
January	......	388	390	......	34	81	32	185	11,375	.486	.560
February	......	402	388	......	664	78	31	313	17,383	.822	.856
March	......	783	422	......	464	101	135	381	23,427	1.000	1.153
April	1,026	452	478	......	582	601	890	672	39,987	1.764	1.968
May	2,654	1,445	1,226	......	1,822	1,205	1,794	1,691	103,976	4.438	5.117
June	2,430	1,328	1,158	......	1,492	955	1,714	1,513	90,029	3.974	4.434
July	1,789	618	506	......	741	178	356	698	42,918	1.832	2.112
August	597	408	413	......	259	131	143	325	19,983	.853	.983
September	415	388	414	......	139	54	73	247	14,697	.648	.723
October	386	385	416	38	137	51	93	270	16,602	.709	.817
November	384	385	414	41	196	86	229	248	14,757	.651	.726
December	379	438	1,097	34	280	54	57	334	20,537	.877	1.011
Total	......	619	610	......	568	298	462	573	415,671	1.504	20.460

RESERVOIR SURVEYS.

Since 1900 numerous surveys of reservoir sites have been made at points where it appeared practicable to impound flood waters to aid in regulating the stream flow.

RESERVOIR SURVEYS IN TRUCKEE BASIN.

In the basin of the Truckee seven of the reservoirs surveyed were recommended for construction, and estimates of their cost were prepared. These estimates were published in Water-Supply and Irrigation Paper No. 68; also in the First Annual Report of the Reclamation Service. The following are the names of the sites surveyed: Lake Tahoe, Donner Lake, Independence Lake, Little Truckee reservoir No. 1, Henness Pass reservoir, Twin Valley reservoir, and Dog Valley reservoir. Of these, Little Truckee No. 1 and Henness Pass reservoirs were resurveyed more in detail in 1903, and revised estimates of their capacity and cost prepared and printed in the Second Annual Report, pages 360–361.

Other reservoir sites in the basin of the Truckee River examined but condemned either on account of small capacity, relatively high cost, lack of sufficient catchment area, or other sufficient reason, are Webber Lake, Little Truckee No. 2, Stampede Valley, Sardine Valley, Martis Creek, Squaw Valley, Monument Peak, and Grass Lake.

RESERVOIR SURVEYS IN CARSON RIVER BASIN.

In the basin of Carson River 21 storage sites were examined, of which 4 only are recommended for construction, as follows: Lower Carson, Alkali Flat, Diamond Valley, and Silver King reservoirs. The other sites are Soda Springs, Silver Queen, Berry or Wolf Creek, Heenan Lake, Pleasant Valley, Mud Lake, Long Valley, Prairie, Harveys Meadows, Hope Valley, Carson, and 5 smaller ones unnamed. These are condemned as being too small, too expensive, or not necessary to the proper control or conservation of the river flow.

During the summer of 1903 a further survey of the Lower Carson reservoir site was made. This work consisted of a traverse of a contour 110.6 feet above the datum of the survey of 1902. The results of this survey were plotted on the original contour map of the site, and the capacity was computed and tabulated as shown on page 363 of the Second Annual Report.

For this reservoir it was proposed to construct a concrete rubble weir dam, but owing to the soft, though impervious, character of the rock reached by borings in the stream bed at the dam site, it has been deemed best to adopt a different type of dam for this location, although plans for the same have not yet been made.

CAPACITY AND COST OF RESERVOIRS.

The follow table gives the estimated capacity and cost of the reservoirs which have been recommended for construction in the development of the Truckee project:

Capacity and cost of reservoirs in Truckee basin.

Name of reservoir.	Capacity.	Cost.
	Acre-feet.	
Lake Tahoe	[a] 200,000	$22,360
Donner Lake	26,900	86,746
Independence Lake	11,725	33,979
Little Truckee No. 1	28,355	81,604
Henness Pass	10,195	49,873
Twin Valley	7,818	41,195
Dog Valley	5,785	32,186
Silver King	22,555	128,040
Diamond Valley	23,280	126,500
Alkali Flat	220,000	600,000
Lower Carson	286,549	480,000
Total	843,162	1,682,488

[a] Net amount which can be drawn annually.

IRRIGABLE LANDS.

The irrigable lands within reach of the Truckee and Carson river waters, outside of about 90,000 acres now under cultivation, comprise a total area of about 460,000 acres, situated as follows:

Irrigable lands commanded by Truckee and Carson rivers.

	Acres.
In Reno Valley, commanded by existing ditches from Truckee River and by small mountain tributaries	12,000
Along foothills north of Truckee River, and in Lemmon, Prosser, Hungry, Spanish Springs, and Warm Springs valleys	73,000
On Pyramid Lake Indian Reservation and adjacent to Wadsworth	35,000
In Carson Sink Valley	200,000
In Churchill Valley	15,000
In Upper Carson Valley	35,000
In Dayton Valley	15,000
In Lower Humboldt, or Lovelock Valley	75,000

Of the foregoing lands, all in Reno Valley, as well as the greater part of those which can be supplied by a high-line canal from Truckee River, and in upper Carson, Dayton, Churchill, and Lovelock valleys are held in private ownership. The Central Pacific Railroad Company is the largest proprietor, though there are a number of persons owning from 1,000 to 25,000 acres each. In Carson Sink Valley about two-thirds of the land still belongs to the public domain.

The investigations of the water supply have not progressed sufficiently to warrant a close estimate of the irrigation possibilities, but it is confidently believed that the water can be controlled so as to reclaim at least 375,000 acres.

CANAL SURVEYS AND CONSTRUCTION.

In the development of the Truckee-Carson project the first canal line surveyed was the Truckee River high-line canal designed to supply water to [illegible] acres of land in the several valleys north of Reno. This comprised a main diversion canal which heads in the left bank of the river at Floriston, Cal., and afterwards traverses a rough, mountainous country for 41 miles and terminates at the divide between Reno and Lemmon valleys. About [illegible] miles of main branches, largely through rugged country, are required to deliver the water to the various valleys.

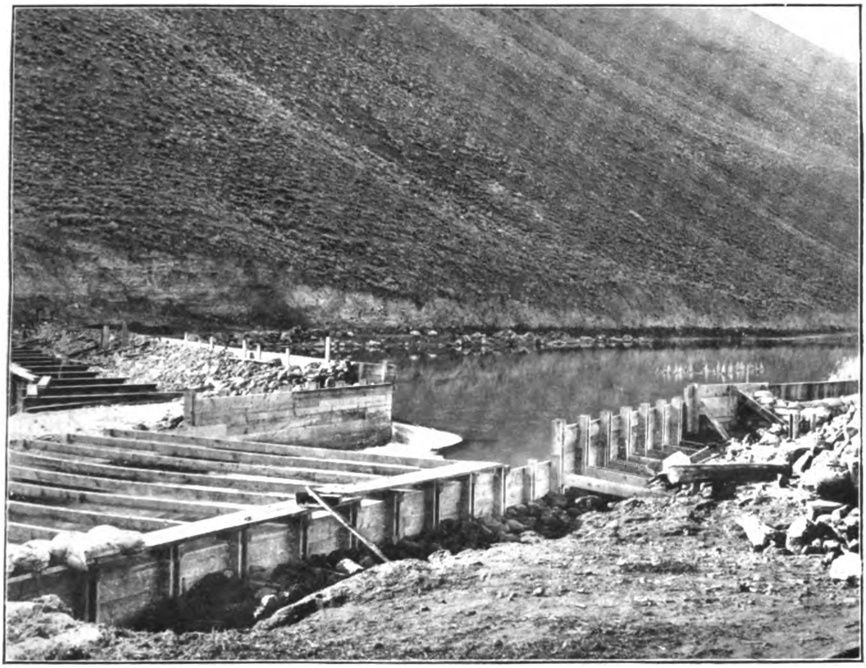
The estimated cost of the diversion canal is $[illegible], being $15.12 per acre of land to be irrigated. While the branches surveyed have not been closely estimated, upon them would cost over half as much more, and when to these is added a proper proportion of the cost of necessary storage works the charge upon the land becomes so nearly prohibitory that it was deemed wise to drop this work for the time being. Accordingly the project of taking water from Truckee River at a point about [illegible] miles above Wadsworth for the irrigation of lands in that vicinity and in Carson Sink Valley was investigated, and it was found not only that this could be done within reasonable limits of cost, but also that the main diversion canal extending from the Truckee to the Carson River could be employed to convey water from the former stream to the lower Carson reservoir site situated on the latter at the canal terminus, where it could be impounded, thus permitting the use of a considerable portion of the Truckee waters for power purposes during the nonirrigating season, and at the same time conserving them for irrigation purposes.

This project also permits of the use of the Truckee and Carson waters in the valley of Carson Sink [illegible] lower Carson reservoir [illegible] of fully [illegible] acres of [illegible] lands, while there are fully [illegible] which can be supplied from the canal directly.

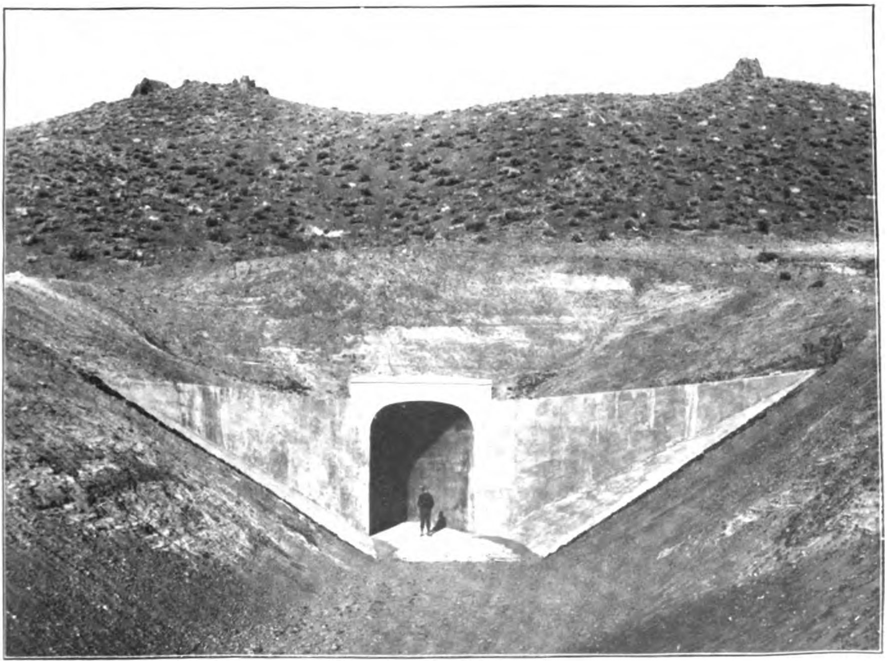
A [illegible] of the lower Truckee canal [illegible] April [illegible]

Plans and specifications [illegible] and proposals for [illegible] Secretary of the Interior in Washington [illegible]

[illegible] M[illegible] & Co., of San Francisco, Cal., and E. B. & A. L. Stone Company, of Oakland, Cal., [illegible] aggregating [illegible] 18 miles [illegible] the propos- [illegible] pp. 365–367.



A. TEMPORARY DAM DIVERTING TRUCKEE RIVER INTO FLUME DURING THE CONSTRUCTION OF HEADWORKS, TRUCKEE-CARSON PROJECT, NEVADA.



B. WEST PORTAL OF TUNNEL AT DIVISION 1, TRUCKEE CANAL, TRUCKEE-CARSON PROJECT, NEVADA.

CANAL SURVEYS AND CONSTRUCTION.

In the development of the Truckee-Carson project the first canal line surveyed was the Truckee River high-line canal, designed to supply water to 73,000 acres of land in the several valleys north of Reno. This comprised a main diversion canal, which heads in the left bank of the river at Floriston, Cal., and afterwards traverses a rough, mountainous country for 31 miles and terminates at the divide between Reno and Lemmon valleys. About 100 miles of main branches, largely through rugged country, are required to deliver the water to the various valleys.

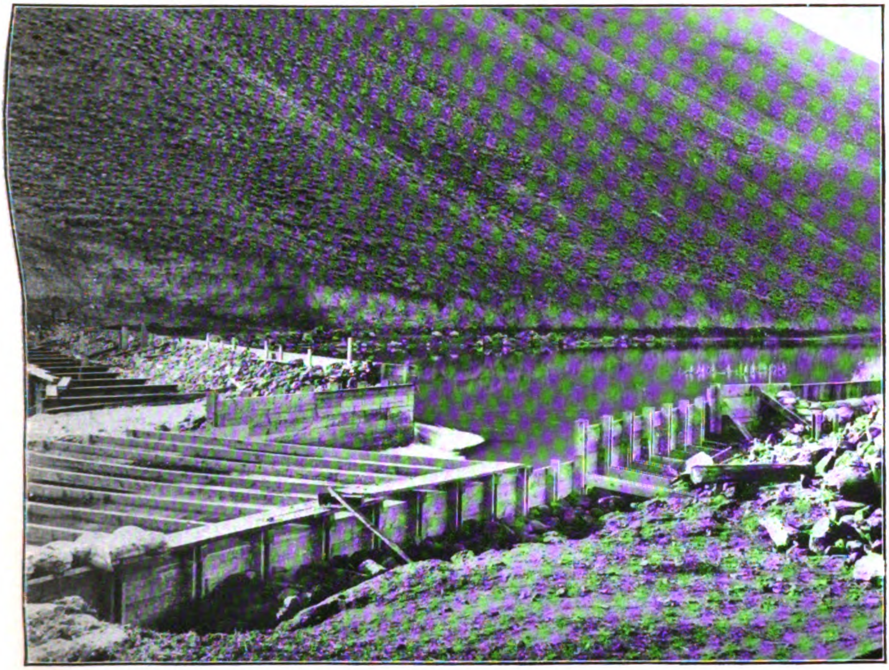
The estimated cost of the diversion canal is $1,103,457, being $15.12 per acre of land to be irrigated. While the branches surveyed have not been closely estimated upon, they would cost over half as much more, and when to this is added a proper proportion of the cost of necessary storage works the charge upon the land becomes so nearly prohibitory that it was deemed wise to drop this work for the time being. Accordingly the project of taking water from Truckee River at a point about 10 miles above Wadsworth for the irrigation of lands in that vicinity and in Carson Sink Valley was investigated, and it was found not only that this could be done within reasonable limits of cost, but also that the main diversion canal, extending from the Truckee to the Carson River, could be employed to convey water from the former stream to the lower Carson reservoir site, situated on the latter at the canal terminus, where it could be impounded, thus permitting the use of a considerable portion of the Truckee waters for power purposes during the nonirrigating season, and at the same time conserving them for irrigation purposes.

This project also permits of the union of the Truckee and Carson waters in the valley of Carson Sink, where, below the lower Carson reservoir, are fully 175,000 acres of irrigable sagebrush lands, while there are fully 125,000 acres more at higher elevations which can be supplied from the canal directly.

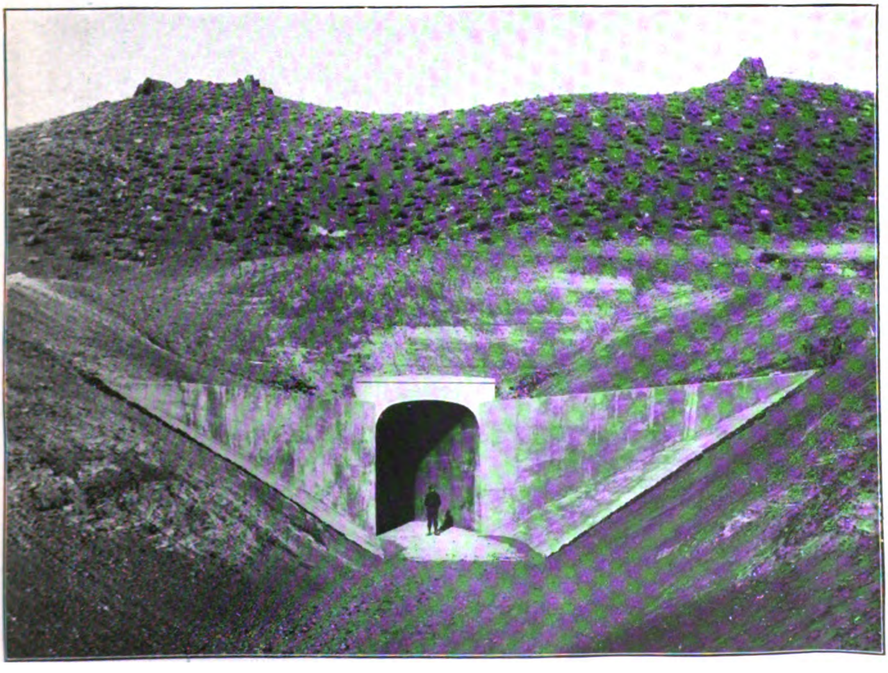
Accordingly it was decided to undertake construction of the lower Truckee canal, and in April its final location was begun.

Plans and specifications were completed early in June, and proposals for its construction were opened by the Secretary of the Interior in Washington on July 15, 1903.

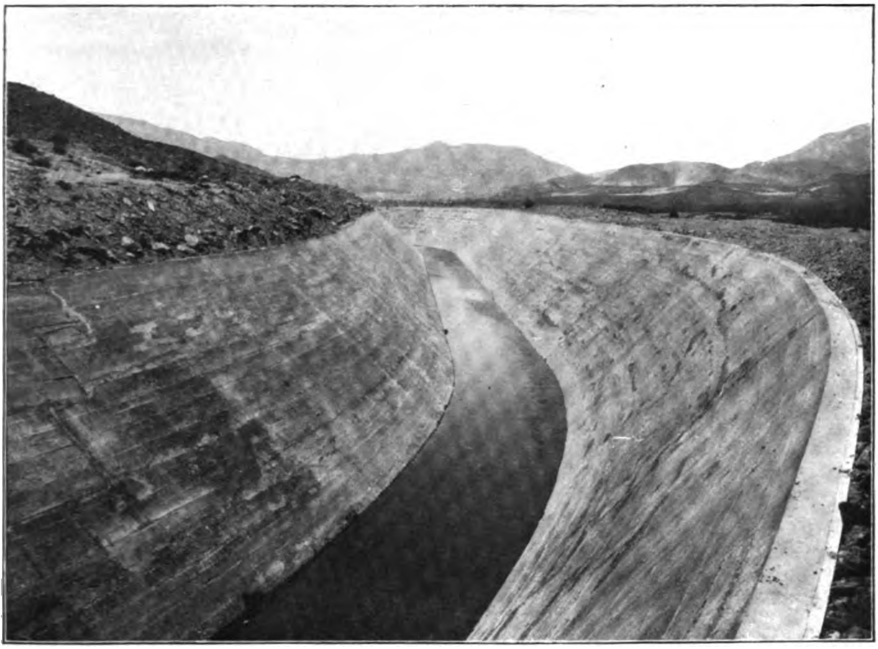
Contracts were awarded to Messrs. C. A. Warren & Co., of San Francisco, Cal., and E. B. & A. L. Stone Company, of Oakland, Cal., the former for the construction of divisions 1 and 2, aggregating about 13 miles in length, and the latter for division 3, about 18 miles in length, they being the lowest bidders. An abstract of the proposals received was printed in the Second Annual Report, pp. 365–367.



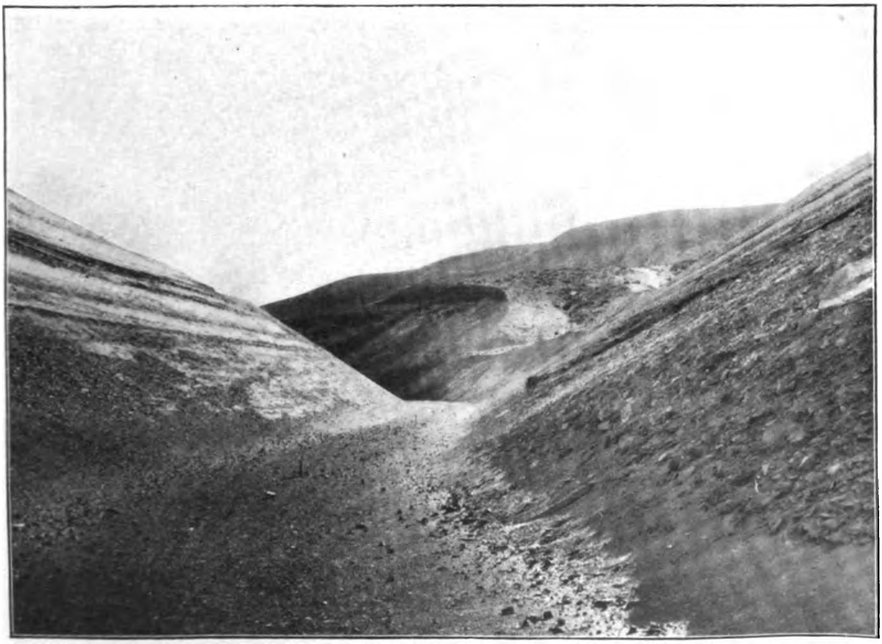
A. TEMPORARY DAM DIVERTING TRUCKEE RIVER INTO FLUME DURING THE CONSTRUCTION OF HEADWORKS, TRUCKEE-CARSON PROJECT, NEVADA.



B. WEST PORTAL OF TUNNEL AT DIVISION 2, TRUCKEE CANAL, TRUCKEE-CARSON PROJECT, NEVADA.



A. PORTION OF TRUCKEE CANAL, TRUCKEE-CARSON PROJECT, NEVADA, SHOWING CONCRETE LINING.



B EARTH EMBANKMENTS ALONG CANAL, TRUCKEE-CARSON PROJECT, NEVADA.

These contracts were executed by E. B. & A. L. Stone Company on August 28, 1903, and by C. A. Warren & Co. on September 3, 1903. Actual construction was begun on division 3 on September 11, and on divisions 1 and 2 on October 2, 1903.

Division 3 was completed September 30, 1904, and divisions 1 and 2, on which an extension of time was asked on account of increased quantity of excavation, especially of class 4 material, are rapidly nearing completion.

Pls. XXXII and XXXIII show photographs of completed works and Pls. XXXIV–XLI show the details of the structures.

Plans and specifications for a portion of the main distributing canals and structures for supplying water to lands in the Carson Sink Valley were perfected in April, and proposals for the construction of 37 miles thereof, involving about 1,500,000 cubic yards of earthwork, with diverting dam, regulating gates, spillways, falls, weirs, and highway bridges, were opened at Reno, Nev., on July 15, 1904.

Contracts were awarded to Pacific Coast Construction Company, of Portland, Oreg., for canal excavation; to R. C. Mattingly, of San Francisco, Cal., for headworks; to San Francisco Construction Company, of San Francisco, Cal., for spillways, falls, and lateral headgates; and to Clarence W. Swain, of Ione, Cal., for highway bridges.

Following is an abstract of the bids received:

Bids received at Reno, Nev., July 15, for construction

FOR WORK UNDER

	Porter Bros.	Utah Cons. Co., Ogden, Utah.	Donald Grant & Co.	Winters, Jones & Co., Spokane.	Mahoney Bros., Salt Lake.	W. D. Clark, Fallon, Nev.
Division 1:						
Class 1, 325,000 cubic yards	$0.22½	$0.16	$0.24½	$0.20	$0.18	----------
Class 2	.35	.40	.45	.35	.35	----------
Class 3	.35	.60	.45	.40	.50	----------
Class 4	1.10	1.00	1.25	.75	.80	----------
Overhaul, 4,700 cubic yards, 100 feet	.01	.01	.01¼	.01½	.01½	----------
Total bid	73,172.00	52,047.00	79,684.00	65,070.00	58,570.00	----------
Division 2:						
Class 1, 200,000 cubic yards	.22½	.14	.21½	.14	.14	----------
Class 2	.35	.40	.45	.35	.35	----------
Class 3	.37	.60	.45	.40	.50	----------
Class 4	1.10	1.00	1.25	.75	.80	----------
Overhaul, 20,000 cubic yards, 100 feet	.01	.01	.01¼	.01½	.01½	----------
Total bid	45,200.00	28,200.00	43,250.00	28,300.00	28,300.00	----------
Division 3:						
Class 1, 215,000 cubic yards	.22½	.13¼	.21	.17	.15	----------
Class 2	.35	.40	.45	.35	.35	----------
Class 3	.37	.60	.45	.40	.50	----------
Class 4	1.10	1.00	1.25	.75	.80	----------
Overhaul, 1,000 cubic yards, 100 feet	.01	.01	.01¼	.01½	.02	----------
Total	48,385.00	28,497.00	45,162.00	36,565.00	32,270.00	----------
Division 4:						
Class 1, 185,000 cubic yards	.18	.13¼	.20½	.14	.15	$0.14
Class 2	.35	.40	.45	.35	.35	.20
Class 3	.37	.60	.45	.40	.50	.30
Class 4	1.10	1.00	1.25	.75	.80	.75
Overhaul, 40,000 cubic yards, 100 feet	.01	.01	.01¼	.01½	.02	.01
Total	33,700.00	24,912.00	38,425.00	26,500.00	28,550.00	26,300.00
Division 5:						
Class 1, 175,000 cubic yards	.18	.13¼	.19	.14	.14	.14
Class 2	.35	.40	.45	.35	.35	.20
Class 3	.37	.60	.45	.40	.50	.30
Class 4	1.10	1.00	1.25	.75	.80	.75
Overhaul, 13,000 cubic yards, 100 feet	.01	.01	.01¼	.01½	.02	.01
Total bid	31,630.00	23,317.00	33,412.00	24,695.00	24,760.00	24,630.00
Division 6:						
Class 1, 210,000 cubic yards	.18	.13¼	.19	.14	.15	----------
Class 2	.35	.40	.45	.35	.35	----------
Class 3	.37	.60	.45	.40	.50	----------
Class 4	1.10	1.00	1.25	.75	.80	----------
Overhaul, 50,000 cubic yards, 100 feet	.01	.01	.01¼	.01½	.02	----------
Total bid	38,300.00	28,325.00	40,525.00	30,150.00	32,500.00	----------
Division 7:						
In water, 2,400 cubic yards	3.50	.60	2.00	.25	----------	----------
Class 1, 165,000 cubic yards	.17½	.13¼	.19	.14	----------	----------
Class 2	.35	.40	.45	.35	----------	----------
Class 3	.37	.60	.45	.40	----------	----------
Class 4	1.10	1.00	1.25	.75	----------	----------
Overhaul, 5,000 cubic yards, 100 feet	.01	.01	.01¼	.01½	----------	----------
Total bid	37,325.00	23,352.00	36,212.00	23,775.00	----------	----------

of about 37 miles of main distributing canals.

SCHEDULE A.

McLean & McSweeney.	W. C. Bradbury, Denver, Colo.	Corey Bros. Cons. Co., Ogden, Utah.	E. B. & A. L. Stone Co., Oakland, Cal.	Deal Bros. & Mendenhall Cons. Co., Springville, Utah.	Springville Cons. Co., Springville, Utah.	San Francisco Cons. Co.	Pacific Coast Cons. Co., Portland, Oreg.	W. F. Beard & Co., Modesto, Cal.	R. A. Moncure, Reno, Nev.
....	$0.18	....	$0.30	....	$0.24	$0.25	$0.15	....	$0.25½
....	.40	....	.50	....	.40	.40	.25	....	.50
....	.50	....	.75	....	.50	.45	.35	....	.50
....	1.10	....	1.00	....	.95	1.25	.80	....	1.25
....	.02	....	.02	....	.01	.01	.01	....	.01
....	58,594.00	....	97,594.00	....	78,047.00	81,297.00	48,797.00	....	82,922.00
....	.162	....	.25	$0.17	.15	.22	.13	....	.22½
....	.40	....	.50	.32	.40	.40	.25	....	.50
....	.50	....	.75	.40	.50	.45	.35	....	.50
....	1.10	....	1.00	.75	.95	1.25	.80	....	1.25
....	.02	....	.02	.01	.01	.01	.01	....	.01
....	32,800.00	....	50,400.00	34,200.00	30,200.00	44,200.00	26,200.00	....	45,200.00
$0.20	.162	$0.16	.25	.17	.15	.19½	.13	....	.20
.50	.40	.40	.50	.32	.40	.40	.25	....	.50
.95	.50	.40	.75	.40	.50	.45	.35	....	.50
1.25	1.10	.75	1.00	.75	.95	1.25	.80	....	1.25
.01½	.02	.01	.02	.01	.01	.01	.01	....	.01
43,015.00	34,850.00	34,410.00	53,770.00	36,560.00	32,260.00	41,935.00	27,960.00	....	43,010.00
.18	.162	.14	.20	.16	.16½	.17½	.13	$0.13	.18
.50	.40	.40	.50	.32	.40	.40	.25	.40	.50
.95	.50	.40	.75	.40	.50	.45	.35	.50	.50
1.25	1.10	.75	1.00	.75	.95	1.25	.80	.90	1.25
.01½	.02	.01	.02	.01	.01	.01	.01	.01	.01
33,900.00	30,770.00	26,300.00	37,800.00	30,000.00	30,925.00	32,775.00	24,450.00	24,450.00	33,700.00
.18	.17	.14	.20	.15½	.16	.17½	.12	....	.18
.50	.40	.40	.50	.32	.40	.40	.25	....	.50
.95	.50	.40	.75	.40	.50	.45	.35	....	.50
1.25	1.10	.75	1.00	.75	.95	1.25	.80	....	1.25
.01½	.02	.01	.02	.01	.01	.01	.01	....	.01
31,695.00	30,010.00	24,630.00	35,260.00	27,255.00	28,180.00	30,755.00	21,130.00	....	31,630.00
.19	.16½	.14	.20	.17	.15	.17½	.12	.14½	.18
.50	.40	.40	.50	.32	.40	.40	.25	.40	.50
.95	.50	.40	.75	.40	.50	.45	.35	.50	.50
1.25	1.10	.75	1.00	.75	.95	1.25	.80	.90	1.25
.01½	.02	.01	.02	.01	.01	.01	.01	.01	.01
40,650.00	35,650.00	29,900.00	43,000.00	36,200.00	32,000.00	37,250.00	25,700.00	30,950.00	38,800.00
....	1.00	....	3.00	.40	.40	2.00	.75	....	3.25
....	.16	....	.20	.15	.16	.17½	.12	....	.18
....	.40	....	.50	.32	.40	.40	.25	....	.50
....	.50	....	.75	.40	.50	.45	.35	....	.50
....	1.10	....	1.00	.75	.95	1.25	.80	....	1.25
....	.02	....	.02	.01	.01	.01	.01	....	.01
....	28,900.00	....	40,300.00	25,760.00	27,410.00	33,725.00	21,650.00	....	37,550.00

Bids received at Reno, Nev., July 15, for construction

FOR WORK UNDER

	Porter Bros.	Utah Construction Co.	Atlantic, Gulf and Pacific Co.
Concrete .... 2,675 cubic yards..	$9.75	$6.00	$8.00
Bearing piles, 12 by 12 inches .... 108 by 20 linear feet..	.40	.36	.36
Driving bearing piles .... per pile..	3.50	5.00	5.00
Sheet piling, 6 inches by 12 feet .... 370 by 20 linear feet..	.21	.24	.22½
Driving sheet piling .... per pile..	2.50	8.00	5.00
Sheet piling, 6 inches by 12 feet .... 320 by 20 linear feet..	.20	.18	.18
Driving sheet piling .... per pile..	2.50	9.00	5.00
Caps and flooring .... 84,960 feet B. M., per M..	40.44	35.00	40.00
Foot planks, 2 by 12 inches .... 585 feet B. M., per M..	33.00	40.00	40.00
Flash boards, bound .... 92, each..	3.75	4.00	5.00
Gates and guides, C. I. .... 94,300 pounds, per pound..	.09	.07½	.08½
Ball-bearing stands .... 23, each..	270.00	275.00	125.00
Steel rising gates .... 4, each..	950.00	810.00	970.00
Steel I-beams .... 8,610 pounds, per pound..	.07½	.05½	.05½
Riprap .... 1,000 cubic yards..	5.30	2.50	5.00
Paving .... 40,000 square feet..	.22	.12	.40
Puddling .... 250 cubic yards..	.60	.50	2.50
Back filling .... 700 cubic yards..	.40	.40	.60
Total bid	69,355.00	54,317.00	69,802.00

FOR WORK UNDER

Concrete .... 2,400 cubic yards..	$10.50	$8.00	$13.75
Steel I's, L's, and T's .... 9,000 pounds, per pound..	.08	.06	.07
Steel gates:			
24 feet 9 inches by 2 feet 6 inches .... 1 each..	889.75	769.00	900.00
20 feet by 2 feet 6 inches .... do....	847.00	746.00	875.00
17 feet by 3 feet 4 inches .... 4 each..	837.00	753.00	880.00
14 feet 6 inches by 2 feet 6 inches .... 2 each..	771.00	687.00	800.00
14 feet 6 inches by 2 feet 1 inch .... do....	660.00	682.00	800.00
22 feet by 2 feet 1 inch .... 1 each..	707.00	729.00	850.00
14 feet 6 inches by 3 feet 4 inches .... 2 each..	708.00	730.00	850.00
Flash boards, bound .... 28 each..	4.00	4.00	5.00
Lumber, O. P .... 25,500 feet B. M., per M..	38.00	40.00	40.00
Riprap .... 300 cubic yards..	7.00	3.00	6.00
Paving .... 25,000 square feet..	.30	.15	.40
Puddling .... 250 cubic yards..	.60	.50	2.50
Rubble masonry .... 2,000 cubic yards..	9.00	8.00	14.00
Back filling .... 1,000 cubic yards..	.40	.40	.60
Old 50-pound rails .... 25 tons, per ton..	....	....	....
Total bid	65,221.00	51,501.00	86,750.00

of about 37 miles of main distributing canals—Continued.

SCHEDULE B.

Donald Grant & Co.	Winters, Jones & Co.	W. C. Bradbury.	E. B. & A. L. Stone Co.	San Francisco Construction Co.	Pacific Coast Construction Co.	R. C. Mattingly.
$16.00	$8.50	$8.60	$9.00	$8.50	$8.00	$6.65
.30	.30	.40	.40	.40	.50	.35
5.00	4.00	2.50	6.00	4.50	8.00	3.00
.15	.16	.27	.25	.25	.25	.22
2.00	4.00	2.75	6.00	4.50	3.00	1.75
.15	.15	.22	.20	.22	.20	.18
2.00	3.00	2.50	6.00	4.50	2.50	1.50
40.00	34.00	45.00	40.00	45.00	32.00	37.25
30.00	34.00	40.00	40.00	45.00	32.00	40.00
1.50	2.00	4.00	3.00	1.50	5.00	1.00
.13	.07	.10	.11¼	.08¼	.11	.06¼
250.00	233.00	275.00	265.00	120.00	250.00	210.00
3,800.00	782.40	660.00	1,050.00	400.00	565.00	810.00
.10	.06	.05½	.06¼	.06	.09	.06
8.00	3.75	5.55	3.00	4.00	2.50	4.00
.40	.13	.24	.15	.15	.13¼	.15¼
1.00	.30	.25	1.50	2.00	.25	3.00
.30	.25	.25	1.00	.25	.20	.30
109,522.00	56,300.00	67,812.00	68,329.00	58,005.00	58,842.00	52,168.00

SCHEDULE "C."

$16.00	$9.50	$10.50	$10.00	$8.50	$9.00	$8.00
.10	.06	.05½	.06¼	.06	.09	.07¼
325.00	744.90	595.00	975.00	300.00	550.00	784.00
325.00	718.20	500.00	925.00	250.00	455.00	757.00
325.00	727.20	550.00	950.00	250.00	480.00	765.00
325.00	647.40	470.00	850.00	220.00	400.00	686.00
325.00	640.80	423.00	825.00	220.00	360.00	670.00
325.00	698.10	510.00	910.00	220.00	452.00	736.00
325.00	699.24	482.00	925.00	220.00	440.00	738.00
2.50	2.00	4.00	3.00	1.50	5.00	1.00
30.00	35.00	43.00	40.00	45.00	35.00	40.00
8.00	3.75	5.55	3.00	4.00	2.50	5.00
.40	.13	.24	.15	.15	.13¼	.17
1.00	.30	.25	1.50	2.00	.25	3.50
16.00	7.00	11.00	13.00	5.40	14.00	7.75
.30	.25	.25	1.00	.25	.20	.30
-----------	60.00	65.00	-----------	60.00	-----------	-----------
89,310.00	53,533.00	65,088.00	69,524.00	43,219.00	61.607.00	52,873.00

These contracts were executed by Clarence W. Swain on August 19, 1904; by Pacific Coast Construction Company, September 9, 1904; by San Francisco Construction Company, September 17, 1904, and by R. C. Mattingly, September 29, 1904. The entire work is required to be completed not later than April 29, 1905.

In order to insure the delivery of water to a larger portion of the irrigable lands of Carson Sink Valley during the irrigation season of 1905, it was deemed advisable to start the construction of a portion of the lateral system not later than the month of November, 1904. In order to avoid the delay incident to advertising for proposals and awarding contracts, the excavation of about 60 miles of minor irrigation and waste ditches was undertaken on force account. Accordingly, work was begun on November 21, 1904, and is progressing satisfactorily.

In order that the work of supervision may be in closer touch with the major part of the work in the field the office in Reno has been abandoned and headquarters have been transferred to Hazen, where an office building, commissary store, and other buildings for the accommodation of the employees and teams of the Service have been constructed.

The work in Nevada is under direct charge of of L. H. Taylor, acting district engineer, with office at Hazen. In this office Mr. William Sergeant, general assistant and special disbursing agent, looks after details in the absence of Mr. Taylor. The drafting, designing, and computation are in charge of A. V. Saph.

The construction work on the main canal and structures was under the immediate direction of William E. Swift up to October 15, with R. R. McGregor, Burt E. Forbes, and Fred A. Temple, each, respectively, in charge of divisions 1, 2, and 3, as his assistants. Each of these assistants has a small corps of instrument men and inspectors, who measure the work and keep account of the men employed, material used, and progress made. These records are embodied in the form of tables showing the estimated cost per cubic yard or other unit of work and the rate of progress. Diagrams are prepared, making possible a comprehensive view of the location of the work, the percentage of the whole completed, the rate of progress which should be made under the contract, and that which has actually taken place.

Since October 15 the assistant engineers in charge of divisions have reported direct to Mr. Taylor.

The construction of the main distributing canals is under the immediate charge of W. S. Russell, with C. V. Taylor and D. W. Hays as assistants, in charge of divisions 1, 2, 3, and 7, and 4, 5, and 6, respectively.

The force account work is under the supervision of W. S. Russell, with A. C. Redman as assistant engineer and R. H. Harpham as foreman.

Other field parties are locating, in advance of letting contracts for construction, the lateral canals in Carson Sink Valley, this work being under the general charge of W. S. Russell, assisted by W. A. Keddie and Harry T. Paterson.

Fred A. Temple, assistant engineer, is engaged in making a definite location of a canal from Carson River, near Dayton, Nev., to divert the flood waters of that stream for storage in Alkali Flat reservoir, preliminary to the preparation of plans and the letting of contracts for construction.

Division 3 of the Main Truckee canal was completed by E. B. and A. L. Stone Company on September 30, 1904.

The topography of the irrigable area is being mapped by B. B. Smith and various assistants. The topographic survey of the lands irrigated and irrigable on Carson River above lower Carson reservoir site in cooperation with the State engineer has been completed, and a similar survey of Reno Valley on Truckee River has been commenced. This work has particular reference to the determination of the existing water rights and consideration of these in connection with future development.

EXISTING WATER RIGHTS.

There are under irrigation and cultivation in the basins of Truckee and Carson rivers about 90,000 acres of land. Of this about 2,000 acres are supplied from the Truckee below the head of the canal now under construction, including lands cultivated by Indians on the Pyramid Lake Indian Reservation, while about 15,000 acres are irrigated in Carson Sink Valley below the lower Carson reservoir, making a total of approximately 17,000 acres of land for which water rights have been acquired within the district designed to be supplied by the irrigation works now projected and under construction.

To obviate possible future complications agreements have been secured from all but four or five of the owners of these lands, exclusive of the Indians, whereby the United States Government agrees to supply from the canals to be constructed by it, free of cost, water for the irrigation of all land now under cultivation and irrigation, and in consideration therefor the landowners agree to convey to the United States all the water rights owned or claimed by them, together with all dams and ditches for the diversion of water.

OPERATIONS IN NEW MEXICO.

By W. M. Reed.

HONDO PROJECT.

There never has been any question that there is plenty of very fertile land that is admirably situated for the utilization of all the water that can be obtained from the Hondo watershed, but so large a portion of the land best fitted, from an economical standpoint, for the use of the water, was in private ownership that it became necessary to make a topographic survey of an extensive area, covering both the land in private ownership and Government land, to ascertain the exact facts in the case, as a preliminary to an attempt to make satisfactory arrangements with the owners of the private lands for the utilization of the water upon the Government lands. Accordingly, in December, 1903, a land subdivision and a topographic party subdivided and classified all the land that would under any circumstances come under the Hondo project.

TOPOGRAPHIC SURVEY.

The topographic survey confirmed the fact that thousands of acres of rich alluvial soil could easily be brought under irrigation from the proposed reservoir.

The lines for ditches were easily determined, the only point requiring care being the selection of locations and of the form of drop that will be necessary, since the fall is too great to permit water to be carried in earth channels without erosion.

A system of distributing ditches has been located on the topographic sheets, but not marked on the ground. Designs for gates and drops will be made in the near future.

DIAMOND-DRILL BORINGS.

Although the outcropping rock in the vicinity of the reservoir is hard blue limestone, lying in uniform layers, it was decided that it should be more carefully studied than was possible from the surface, and therefore a diamond drill with hand power was used in exploring the formation beneath the surface of the bottom of the reservoir and about the sites chosen for the dams and headworks.

Fifteen borings were made, and a very careful record of material encountered was kept and submitted, with samples of material, to a board of consulting engineers, which consider the formation sufficiently safe for the work contemplated.

Borings, Hondo River dam site, New Mexico, 1903.

Hole No.	Depth to rock.	Total depth.	Surface elevation.	Bottom elevation.
	Feet.	*Feet.*	*Feet.*	*Feet.*
1	21.0	37.3	3,845.54	3,804.24
2	29.5	33.6	3,847.54	3,813.94
3	35.0	38.7	3,857.54	3,818.84
4	20.7	31.0	3,879.54	3,848.54
5	26.3	35.6	3,847.54	3,811.94
6	37.7	38.7	3,885.54	3,846.84
7	10.8	11.6	3,847.54	3,835.94
8	62.5	65.0	3,847.54	3,782.54
9	36.8	44.0	3,869.54	3,825.54
10	1.0	78.4	3,859.54	3,781.14
11	80.2	91.8	3,862.54	3,770.74

Boring at hole No. 1:

0 to 21 feet	Red clay.
21 to 22 feet	Soft rock.
22 to 27.5 feet	Yellow clay.
27.5 to 30.5 feet	Soft rock.
30.5 to 37.5 feet	Limestone.

Boring at hole No. 2:

0 to 9 feet	Soil.
9 to 29.5 feet	Yellow clay.
29.5 to 31.3 feet	Soft rock.
31.3 to 33.6 feet	Limestone.

Boring at hole No. 3:

0 to 3.5 feet	Soil.
3.5 to 17 feet	Yellow clay.
17 to 20.9 feet	Gypsum.
20.9 to 27.5 feet	Red clay.
27.5 to 35 feet	Gypsum.
35 to 38.7 feet	Limestone.

Boring at hole No. 4:

0 to 5 feet	Yellow clay.
5 to 6 feet	Gypsum.
6 to 11 feet	Red clay and gypsum.
11 to 13.3 feet	Gypsum.
13.3 to 20.7 feet	Clay.
20.7 to 22.8 feet	Soft rock.
22.8 to 31 feet	Limestone.

Boring at hole No. 5:

0 to 3 feet	Soil.
3 to 26.3 feet	Yellow clay.
26.3 to 28.8 feet	Soft rock.
28.8 to 35.6 feet	Limestone.

Boring at hole No. 6:

0 to 2.5 feet	Soil.
2.5 to 13.5 feet	Yellow clay.
13.5 to 17.3 feet	Gypsum.
17.3 to 25 feet	Clay and gypsum.
25 to 29.7 feet	Gypsum.
29.7 to 37.7 feet	Yellow clay.
37.7 to 38.7 feet	Limestone.

Boring at hole No. 7:

0 to 10.8 feet	Soil.
10.8 to 11.6 feet	Limestone.

Borings at hole No. 8:

0 to 30 feet	Soil.
30 to 41 feet	Yellow clay.
41 to 51.5 feet	Cobblestones and clay.
51.5 to 61 feet	Loose cobblestones.
61 to 62.5 feet	Clay.
62.5 to 64 feet	Soft limestone.
64 to 65 feet	Hard limestone.

Borings at hole No. 9:

0 to 5 feet	Soil.
5 to 12.5 feet	Sand.
12.5 to 20 feet	Cobblestones.
20 to 36 8 feet	Yellow clay.
36.8 to 38 feet	Soft limestone.
38 to 44 feet	Hard limestone.

Borings at hole No. 10:

0 to 1 foot	Soil.
1 to 12.8 feet	Hard limestone.
12.8 to 29.7 feet	Broken limestone.
29.7 to 31.7 feet	Clay and broken rock.
31.7 to 33.6 feet	Clay and gypsum.
33.6 to 55.6 feet	Gypsum.
55.6 to 56.3 feet	Red clay.
56.3 to 59.3 feet	Gypsum.
59.3 to 74 feet	Clay.
74 to 78.4 feet	Gypsum.

Borings at hole No. 11:

0 to 11.1 feet	Clay.
11.1 to 22 feet	Broken limestone.
22 to 25 feet	Clay.
25 to 30 feet	Cavity.
30 to 64.4 feet	Broken rock and cavities.
64.4 to 70.2 feet	Gypsum.
70.2 to 71.9 feet	Clay.
71.9 to 73.4 feet	Cavities.
73.4 to 76.8 feet	Loose rock.
76.8 to 79.8 feet	Gypsum.
79.8 to 80.2 feet	Clay.
80.2 to 88.4 feet	Limestone.
88.4 to 91.8 feet	Gypsum.

PLANS AND SPECIFICATIONS.

The plans and specifications which have been approved by the consulting board contemplate the use of a natural basin for a portion of the storage reservoir and necessitate only rather low embankments. The water is to be diverted by means of an earthen dam, with a maximum height of 20 feet. The dam is to have a crown width of 20 feet and slope (water side) of 3½ horizontal to 1 foot vertical, downstream side 2 feet horizontal to 1 foot vertical. The water is to be conveyed through a canal with a bottom width of 70 feet and slopes of 2 feet horizontal to 1 foot vertical, with a grade of 6 feet to 1,000.

For a portion of its length the canal will have but one bank. This is at the crossing of a rather flat draw, and is intended as a settling basin to take the heavier silt that is carried by the Hondo when running at high velocity.

The canal is provided with a weir near its lower end, over which the top one-third of the water will flow, allowing the silt to gather behind and be sluiced out at intervals, as necessity requires, through sluice gates constructed almost opposite the weir. The silt-laden water will be returned to the original channel of the river. The canal is to be supplied with five sluice gates and two spill gates.

The sluice gates are to be placed at the bottom of the canal and used exclusively for the purpose of getting rid of the silt that has been deposited in the canal owing to the reduced velocity of the water after leaving the river.

The spill gates, in addition to acting as sluice gates, are so arranged that they furnish automatic spillway, the water passing over their tops, which are arranged with 3-foot safety below the top of the earthen canal banks.

All sluice and spill gates will be constructed of reenforced concrete. The only timber to be used is for flash boards in a portion of the weir.

In addition to the spillways along the canal, there will be left an open space across a rather level and well-grassed section to the south of the dam where, in cases of extreme high water, a large volume could be taken care of without material injury. It is expected that only in rare cases would this means of escape be used, and as the water would not return to the river for some distance no harm would be done.

In addition to the natural basin, it is proposed to increase the storage by means of five embankments, constructed between hills, which raise the storage capacity about fourfold.

None of the embankments will have more than 20 feet of water against them. They will all have a crown width of 20 feet, with inside slopes 3 feet horizontal to 1 foot vertical and outside slopes of 2 feet horizontal to 1 foot vertical. The water side is to have a rock facing 1 foot in thickness.

The outlet will be through iron pipes 3 feet in diameter, laid on concrete foundations and provided with concrete collars to prevent the water from creeping along them. The pipes will take the water from a tower constructed of reenforced concrete. There will be gate valves on each pipe, and there will also be a gate on the tower to regulate the flow into the tower if condition of other valves should demand it. Plans of the spillway and outlet canal are shown on Pls. XLII and XLIII.

WATER USERS' ASSOCIATION.

An association known as the Rio Hondo Reservoir Water Users' Association has been formed and is actively at work. The 10,000 acres of land, the amount required for this project, has been subscribed and the titles to the land are now being investigated. No delay is anticipated from any dealings with this association.

CONSTRUCTION.

In response to advertisement for proposals for the construction of the reservoir and canals of the Hondo project eleven bids were received and opened on September 6, 1904, at the office of the Reclamation Service, at Roswell, N. Mex., and after inspection and arrangement were sent to Washington, with the recommendation of the project board.

The following is an abstract of the proposals received:

Bids for work on reservoir and canals, Hondo project, New Mexico.

	Taylor-Moore Construction Co., Hillsboro, Tex.	Wood, Bancroft & Doty, Omaha, Nebr.	Maney Bros. & Spencer, Oklahoma City, Okla.	Orman & Crook, Pueblo, Colo.	Carroll Contracting Co., St. Louis, Mo.	W. W. Atkinson, Colorado Springs, Colo.	Whitescarver Construction Co., Trinidad, Colo.	Cazier Construction Co., Roswell, N. Mex.	Slinkard Construction Co., Roswell, N. Mex.	F. C. Youmans, Kansas City, Mo.	De Remer & Olson, Denver, Colo.
Schedule No. 1:											
74,000 cubic yards excavation, class 1	$0.12¼	$0.15	$0.13¼	$0.17	$0.23	$0.20	....	$0.16	$0.15	....	$0.15
100 cubic yards excavation, class 2	.46	.40	.45	.35	.50	.60	....	.45	.40	....	.35
100 cubic yards excavation, class 3	.65	.40	.60	.37	.75	1.00	....	.35	.40	....	.40
1,000 cubic yards overhaul	.0131	.01¼	.02	.01¼	.02	.02	....	.01¼	.02	....	.01
1,000 square yards riprap	.42	.90	.75	1.00	1.00	1.25	....	1.25	.85	....	.95
100 cubic yards puddling	.92	.40	1.00	.80	2.00	2.00	....	.75	1.00	....	.10
Schedule No. 2:											
1,000 cubic yards excavation, class 1	.12¼	.15	.15	.16	.30	.21	$0.16	....	.15	....	.15
100 cubic yards excavation, class 2	.46	.40	.45	.35	.50	.60	.40	....	.40	....	.35
100 cubic yards excavation, class 3	.65	.40	.60	.37	.75	1.00	.80	....	.40	....	.40
30,000 cubic yards excavation, class 4	.83	.90	.85	.85	1.40	1.30	.95	....	.69	....	.70
200 cubic yards overhaul	.0131	.01¼	.02	.01¼	.02	.02	.02	....	.02	....	.01
100 square yards riprap	.42	1.00	.75	1.00	1.00	1.25	.95	....	.85	....	.95
100 cubic yards puddling	.92	.40	1.00	.80	2.00	2.00	.70	....	1.00	....	.10
Schedule No. 3:											
288,000 cubic yards excavation, class 1	.12¼	.15	.14¼	.19	.21	.21	....	.21¼	.15¼	....	.14¼
100 cubic yards excavation, class 2	.46	.40	.45	.35	.50	.60	....	.45	.40	....	.85
100 cubic yards excavation, class 3	.65	.40	.60	.37	.75	1.00	....	.35	.40	....	.40
1,000 cubic yards overhaul	.0131	.01¼	.02	.01¼	.02	.02	....	.01¼	.02	....	.01

Bids for work on reservoir and canals, Hondo project, New Mexico—Continued.

	Taylor-Moore Construction Co., Hillsboro, Tex.	Wood, Bancroft & Doty, Omaha, Nebr.	Maney Bros. & Spencer, Oklahoma City, Okla.	Orman & Crook, Pueblo, Colo.	Carroll Contracting Co., St. Louis, Mo.	W. W. Atkinson, Colorado Springs, Colo.	Whitescarver Construction Co., Trinidad, Colo.	Cazier Construction Co., Roswell, N. Mex.	Slinkard Construction Co., Roswell, N. Mex.	F. C. Youmans, Kansas City, Mo.	**De Remer & Olson, Denver, Colo.**
Schedule No. 3—Continued.											
10,700 square yards riprap..	$0.42	$0.90	$1.00	$1.00	$1.00	$1.25	....	$1.25	$0.85	....	$0.95
1,000 cubic yards puddling.	.92	.40	1.00	.80	2.00	2.00	....	.75	1.00	....	.10
Schedule No. 4:											
80,000 cubic yards excavation, class 1..............	.12½	.15	.14½	.16	.21	.21	$0.16½	.18	.15	....	.15
1,000 cubic yards overhaul.	.0131	.01½	.02	.01½	.02	.02	.02	.01½	.02	....	.01
5,600 square yards riprap..	.42	1.25	1.00	1.00	1.00	1.25	.95	1.25	.85	....	1.05
100 cubic yards puddling..	.92	.40	1.00	.80	2.00	2.00	.70	.75	1.00	....	.10
Schedule No. 5:											
162,000 cubic yards excavation, class 1..........	.04	.15	.16	.18	.21	.21	....	....	.15½	....	.14½
150,000 cubic yards overhaul.....................	.0131	.01½	.02	.01½	.02	.02	....	....	.02	....	.01
9,200 square yards riprap..	.42	.80	.90	1.00	1.00	1.25	....	....	.85	....	1.05
100 cubic yards puddling..	.92	.40	1.00	.80	2.00	2.00	....	....	1.00	....	.10
Schedule No. 6:											
100 cubic yards excavation, class 1..............	.15	.25	.16	.45	.50	.50	.40	....	....	$0.50	.16
100 cubic yards excavation, class 2..............	.46	.75	.45	.75	.60	1.00	.70	....	....	.75	.35
100 cubic yards excavation, class 3..............	.65	.75	.60	1.00	.75	2.00	.80	....	....	1.00	.40
100 cubic yards excavation, class 4..............	1.50	1.50	.85	1.75	2.50	3.00	1.20	....	....	1.50	.70
100 cubic yards overhaul..	.0131	.01½	.02	.01½	.02	.05	.02	....	....	.02	.01
408 square yards riprap....	.42	1.00	1.00	1.00	1.00	1.50	1.25	....	....	1.50	.95
100 cubic yards puddling..	.92	.40	1.00	.80	2.00	2.00	.70	....	....	2.00	.10
1,600 cubic yards concrete.	6.90	8.50	9.00	6.00	9.00	10.00	8.50	....	....	7.00	7.75

100 cubic yards masonry ..	8.90	5.00	10.00	12.00	8.00	12.00	9.50	....	....	6.50	5.00
12 M feet, timber construction	45.00	50.00	45.00	45.00	60.00	60.00	40.00	....	....	50.00	45.00
75 piles	13.00	9.00	15.00	18.00	12.00	15.00	15.00	....	....	12.00	13.80
100,000 pounds structural steel gates, etc...........	.074	.09	.10	.14	....	.08	.07	....	....	.08¼	8.00
391 feet cast-iron pipe......	11.60	10.00	10.00	18.00	16.00	14.00	19.00	....	....	10.75	10.00
Total	127,476.00	174,897.00	176,795.00	199,766.00	236,580.00	238,890.00	79,035.00	110,890.00	141,014.00	27,492.00	957,091.00

The contracts were awarded on November 29 to Taylor-Moore Construction Company on schedules 1, 3, 4, 5, and 6, and to Slinkard Construction Company for schedule 2.

URTON LAKE PROJECT.

TOPOGRAPHY AND LAND SUBDIVISION.

During the winter of 1903-4 a topographic and subdivision survey was made of the district that would come under irrigation by the construction of the Urton Lake project. One hundred and ten square miles of country were mapped, 215 miles of section lines were run, and 320 corners were set and marked.

The soil was in some instances almost pure sand, but it was prevailingly a sandy loam. The contour interval was 5 feet.

The classification of the land was as follows:

Lands lying under Urton Lake project, New Mexico.

	Acres.
First class	32,000
Second class	9,000
Third class	30,000

Outside of this mapped district is a fine grazing country that can not be fully used owing to the lack of water, much of which could be utilized with water conducted in the distributing canals.

Very little of the land had been filed upon before the commencement of work by the Reclamation Service, but a number of homestead entries were made during its progress. However, almost all of the entrymen have failed to meet the requirements of the law and the entries are now subject to cancellation.

During the survey the lines for distributing canals were indicated on the maps and for a portion of the distance were staked upon the ground. A topographic map was also made of the reservoir site and of a strip on each side of the inlet canal. For some distance above and below the dam site a very careful topographic survey was made of the river banks.

TESTING.

The inlet canal is about 35 miles in length. It leaves the river at the Adam site, about 12 miles above old Fort Sumner, and is carried along the east slope of the valley. It crosses three creeks, usually dry, but in time of rains carrying large streams, which must be provided for in the event of construction.

The entire canal line has been tested by the use of steel drills driven to the proposed grade line. A profile has been made of the entire line, showing the different kinds and amount of material to be found along it.

The dam site has been prospected with an ordinary steel drill, but this is not deemed sufficient, and estimates of cost can not be made until diamond-drill prospecting has been concluded.

The diamond drill is also needed to determine the material in the east rim of the reservoir, for the water must be taken through this by means of a tunnel, and it is necessary to know its nature before plans and estimates can be made that will be even approximately accurate.

PLANS.

A set of general plans for the dams, spillways, flood gates, crossings, bridges, etc., of this project have been made.

The canal has been planned in line with the recommendation of the consulting board, and the quantities of the different kinds of material have been calculated. The climate in New Mexico being such that work can be carried on during the winter, further work was postponed until men and machinery employed in more northern districts should be compelled to stop work on account of cold weather and would become available. The diamond-drill work necessary for this project will be completed this winter.

STREAM MEASUREMENTS.

As several arroyos of considerable length enter Pecos River below the gaging station at Santa Rosa, it was thought that the records of that station would not give very accurate data as to the water available for this project. Therefore in June a gaging station was established at the proposed dam site. As this point is far from railroads and inaccessible, an assistant hydrographer remained upon the ground for six weeks in order to get enough measurements to plat a curve for the discharge. Daily readings are now being taken by an observer who lives in the neighborhood. The floods of the latter part of September and first part of October broke the gage rod at the elevation of 10 feet. This has now been replaced and the readings will be continued.

LAS VEGAS PROJECT.

That a reservoir site existed in the vicinity of Las Vegas (Pl. XLIV) has been a matter of general knowledge for some time. The Geological Survey made a general survey of this section in 1889 and had the sheets printed and distributed. The people of Las Vegas and vicinity called the attention of the Reclamation Service to this site and requested that it be examined.

The first steps were taken in June, 1903, when an examination was made of the site by the district engineer, and a report made upon it by an engineer employed by an association of the citizens of Las Vegas.

Gaging stations were established at about the same time upon the streams that would afford water for this project, and a record has been kept of the daily discharge since that time.

In April of the present year the work was taken up by a small party and carried far enough to gain a knowledge of conditions and to make estimates of the capacity of the reservoir, the land subject to irrigation, and the costs of the necessary works to carry the project to completion. The amount of available water and the water-holding properties of the rocks have not been determined.

WATER SUPPLY.

This reservoir will be supplied by diverting the flood waters of Sapello, Gallinas, San Guijuela, and Arroyo Pecos creeks. The total drainage area is about 279 square miles, and as the elevation of the entire area is more than 6,500 feet above sea level and the rainfall at the 6,500-foot level is more than 15 inches per annum, there should be ample water at least once each year for filling the reservoir, which has a capacity of 38,500 acre-feet.

LAND OWNERSHIP.

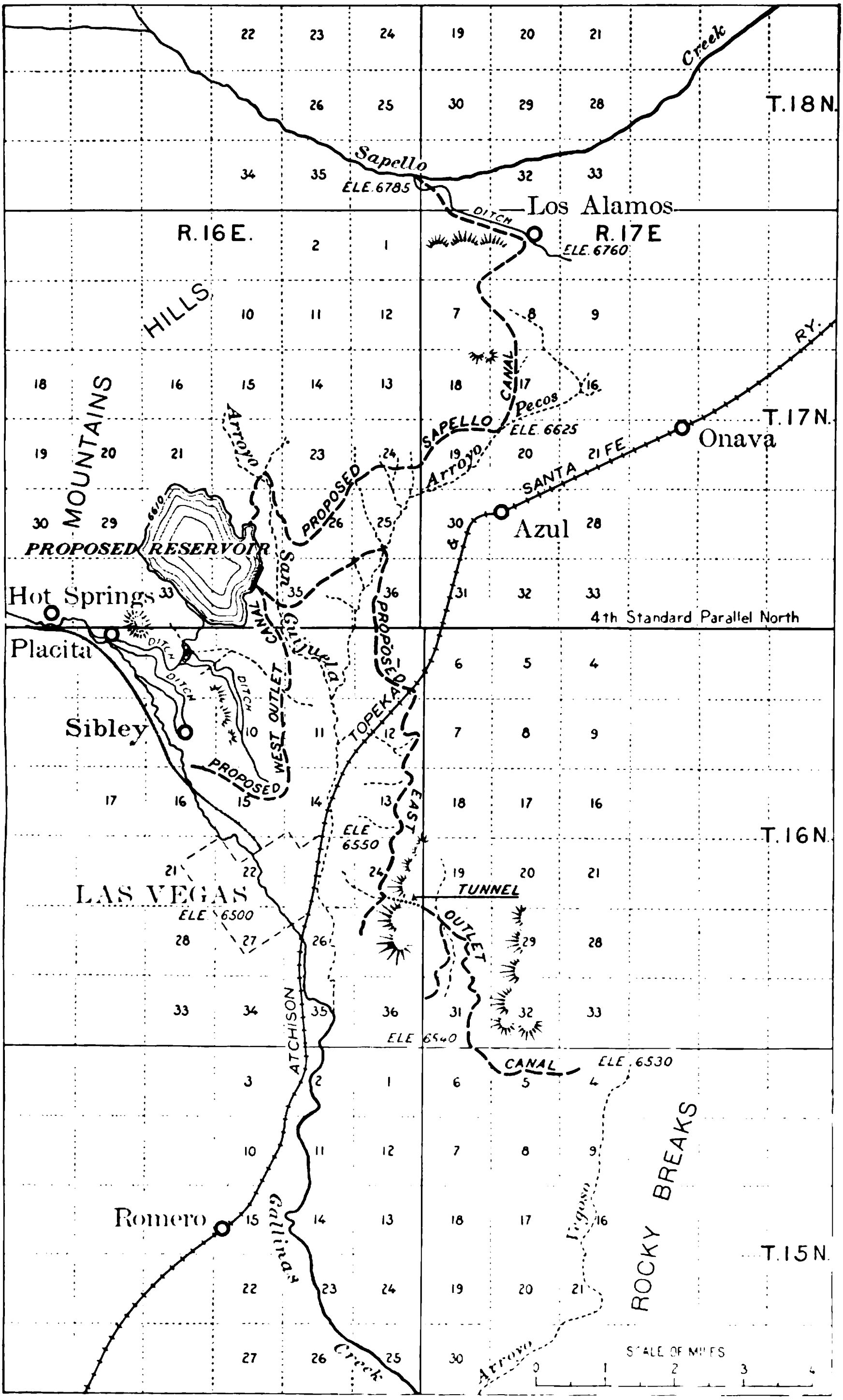
The land upon which this project is situated is all included in what is commonly known as the Las Vegas grant.

For many years this property was in litigation and its title had to be carried through all the courts. Finally, by a court decision, the title was vested in the community of Las Vegas, and the property has been managed by a board of trustees acting in conjunction with the court.

Under ordinary circumstances these conditions would preclude all possibility of the Government taking hold of the project under the terms of the reclamation act, but before any steps were taken toward a survey the board of trustees signified their willingness and desire to transfer to the United States all lands necessary for the construction and maintenance of reservoirs, canals, spillways, and other works in connection with the system, and also all lands that would come under the system and be subject to irrigation, thereby placing the land in the same condition as though it had never been out of the ownership of the United States, allowing the land to be disposed of under the homestead law and in accordance with the terms of the reclamation act.

TOPOGRAPHY.

A topographic survey has been made on a scale of 1,000 feet to the inch, with 5-foot intervals, of the reservoir site, of a strip on each side of the intake canals, and of the area that would be subject to irrigation under this system.



GENERAL MAP OF PROPOSED LAS VEGAS PROJECT NEW MEXICO.

The original maps of this district made in 1889 were upon a much smaller scale and did not give sufficient details for the desired information; however, they gave a good check on recent work.

The topography is such that the diversion of the waters from the streams will not involve difficult engineering features. The construction of the distributing canals, however, will be more difficult. Most of the land to be irrigated lies southeast of Las Vegas. It was the general impression that a canal to reach this could be carried over the plateau to the east of Las Vegas, but closer surveys showed that this was impossible, the grade line was found to wind around some steep, sharp-pointed bluffs that are composed of material that is unsuitable for carrying water. The best solution of this difficulty has been found to be a tunnel running from the head of a small arroyo through the hill to the head of another. By this means some grade can be saved and probably much loss of water prevented. A very careful map of this district has been made in order that a close study may be made for the purpose of betterments in the line.

The topography of the land subject to irrigation was carefully mapped, for it was found that the area is limited and care must be taken in order to determine whether there is enough land to stand the expense of the project.

GENERAL BENEFITS.

Las Vegas is situated on the main line of the Atchison, Topeka and Santa Fe Railroad; this was the first railway to enter a very large territory and the towns built along its route have become distributing points for large areas.

Las Vegas had been a town for many years before the advent of a railroad into the Territory. It is located on the Gallinas River, a perennial stream, only a few miles distant from the Las Vegas hot springs. When the railroad reached it, it immediately became a busy town. The population increased, many new business houses were built, and it became one of the leading towns of the Territory. Conditions remained unchanged until other railroads were built into the adjoining territory and took away a large part of its wholesale and commission business; after this the population gradually grew less. At present the constant or perennial flow of the streams is fully utilized, but it does not furnish sufficient water to produce enough food or to supply employment for the entire population. The flood waters that annually go to waste, if economically stored and applied, would furnish employment and food for a population already on the ground and apparently willing to work.

This portion of New Mexico imports, rather than exports, the common necessities of life, and, owing to circumstances above mentioned, must decrease in population unless new industries are developed

Many of the thinking citizens realize this condition and are anxious to offer assistance to any enterprise that will alleviate present conditions. The feeling seems to be almost unanimous that everything reasonable shall be done by the trustees of the grant and the citizens in general to aid the Government should the project prove feasible and construction be undertaken.

REPORTS.

A report upon this project has been made by the district engineer. This report, which includes maps of the district, tables, estimates of cost of construction, and a short history of the legal phases of the Las Vegas grant, has been submitted by the chief engineer to a project board, which in the near future will meet at Las Vegas, go over the ground, plans, and estimates, and report upon the feasibility of the project.

RECONNAISSANCE OF CANADIAN RIVER.

Frank S. Dobson made a partial reconnaissance of irrigation possibilities on Canadian River drainage in April, 1904. From his report it appears that between Dorsey, N. Mex., and Springer, N. Mex., the valley varies from 5 to perhaps 25 miles in width, and is of first class land, sloping gently away from the river to the hills. All of the land is in the Maxwell land grant, the owners of which have secured United States patents for their land, so if anything is done in the valley it would benefit only the few owners of the grant.

The drainage basin of Canadian River above Dorsey, N. Mex., has an area of less than 800 square miles, in the low foothills of the Rocky Mountains. The river is very small, though at times it carries large floods, but never for more than two or three days. Hence there is doubt as to the water supply.

Ocate River drains about 400 square miles of mountainous country, some of the mountains being covered with snow the year round. Except for the last two years it has been a running stream throughout the year, and during spring rains and thaws is reported to carry enormous floods. It runs in an easterly direction, nearly along the county line between Colfax and Mora counties, and empties into Red River in T. 23 N., R. 23 E., New Mexico principal meridian.

In the first 3 miles above Sweetwater Creek the river valley rises 125 feet; in the next 1½ miles the rise is 150 feet to the mouth of the Ocate Canyon; thence for 2 miles up the canyon the rise is from 75 to 100 feet per mile.

The canyon varies in width from 1,000 to 2,000 feet, with average side slopes from river to bluffs of 1½ to 1; the bluffs are of solid red sandstone; the side slopes of red sandy loam and gravel; the river bed is covered with large bowlders, the smallest about 4 to 6 inches in diameter; the side slopes are sparsely covered with gramma grass and cedar trees. The canyon becomes a little smaller farther up, and the fall is about the same; hence there is no storage in it.

The fall of Sweetwater Creek for the first 5 miles above its mouth is about 12 feet per mile, and the highest possible dam would be 25 feet high and 2,600 feet long; this dam would store 11,000 acre-feet and the backwater would cover 1,000 acres. Owing to the earth formation in this valley the dam would necessarily be of earth. If the dam had 10-foot crown, 3 to 1 slope on upper and 2 to 1 slope on lower face, 80,000 cubic yards of fill would be required.

Water could be carried to this reservoir from Ocate River by a canal 2 miles long. Sweetwater Creek has but little flow, as is shown by the fact that the channel disappears and the bed is covered with grass.

The valley is of first-class land, mostly gray loam, covered with a thick growth of gramma grass. It is settled almost entirely by Mexicans, who have lived here some time and have secured United States patents for their lands. Very few have more than 160 acres. These Mexicans have done little or no farming. Each has a small herd of sheep or cattle, which are pastured on the lands.

Ocate Valley, below the mouth of Sweetwater Creek, is dammed at a number of places by small dams from 10 to 12 feet high. These catch a little of the spring floods, and some of them hold water the year round. They are used for watering stock and in some cases for diverting river water, which is distributed over the land by means of small ditches, thus irrigating the pastures to some extent.

From the reservoir to Colmer, N. Mex., a distance of 4 miles, Ocate River falls 40 to 60 feet per mile, the general slope of the land being the same. The valley slopes gently away from the river, with occasional small bluffs about 25 to 50 feet high, varying in width from 500 to 2,000 feet. The land is first class throughout and is covered with a thick growth of gramma grass. For 2 miles each side of the river this land is mostly taken up by Mexicans.

According to the settlers in and around the valley, this river has, except within the last two years, flowed during the entire year, but under the existing conditions there is some doubt as to the sufficiency of the water supply.

All through Ocate Valley there are a number of small lakes, the largest of which is Colmer Lake. This lake, with inlet and outlet canals, has been surveyed and canals have been built. Its capacity, with no extra fill, is about 1,044 acre-feet, covering 200 acres. The lake is owned and operated by three different persons, irrigating about 500 acres. Owing to a low ridge on the west side of the lake, the greatest possible depth of the lake is 35 feet. This would necessitate a dam on the east side 2,500 feet long, with a maximum depth of 25 feet, requiring 100,000 yards of material, using a 10-foot crown and 3 to 1 slope on upper and 2 to 1 slope on lower face. The capacity of the lake would then be 18,000 acre-feet, covering 750 acres. This lake would be filled from the Ocate by a canal 5 miles long, if the water supply were sufficient.

Although large floods occur at times during the spring, yet there is some question as to a sure supply each year. Last year not enough water was obtained to fill the lake to its present height, and the owners have not been able to irrigate for nearly a year. Last year, however, was exceptionally dry. It is possible that such a year may occur again.

The land here is a first-class sandy loam, covered with a thick growth of gramma grass, and is very fertile. There is plenty of well water all through the valley. The land below the lake is mostly vacant, only perhaps a half-dozen claims having been taken up by settlers, most of whom have secured patents for their homesteads. Six thousand acres of land can be reached from this reservoir on the north side of the Ocate and 15,000 acres on the south side.

Red River from the mouth of Cimmaron Creek to the mouth of Ocate River has a fall of 40 feet per mile.

At a point 4 miles below the mouth of Cimmaron Creek, in sec. 22, T. 24 N., R. 23 E., Red River runs into a canyon that increases in depth from 50 to 200 feet in 3 miles, and varies in width from 300 to 500 feet, with side slopes 1½ to 1 from river to bluffs. The bluffs are of red sandstone, and the slopes are of red sand and coarse gravel. The slopes are covered with a thick growth of cedar trees.

In sec. 34, T. 24 N., R. 23 E., Chico Creek runs into Red River, draining from the northeast. This creek runs through a canyon about one-half mile long, 100 feet deep, and 300 feet wide before emptying into Red River. Above this canyon the valley is 2 miles wide, remaining so for about 5 miles above the canyon.

This was said to be an ideal reservoir site, but the fall was found to be about 50 to 75 feet per mile, hence there is no storage on the creek. Furthermore, this creek has a drainage area of only 150 square miles and there is serious question as to the water supply.

The land all through this valley is first class, with occasional rocky points.

Below the mouth of Ocate Creek Red River Canyon increases in depth from 200 to 700 feet in 10 miles, the width from bluff to bluff varying from 1,000 to 2,000 feet, while side slopes average 1½ to 1 from river bed to bluffs. The river bed and the side slopes are covered with large bowlders of red sandstone. The bluffs are of solid red sandstone.

In this canyon, at places where the side slopes are not too steep, are a number of small farms, varying in size from 10 to 50 acres. These farms are owned mostly by Mexicans, who irrigate from the river. The soil is very fertile in places, consisting of reddish sandy loam. All through the canyon there is a thick growth of pine and cedar trees and a few cottonwoods. The river falls on an average 40 feet to the mile. It is very crooked, running on a bed usually of sand and gravel, but in a few places on solid rock.

In April there was about 10 second-feet flowing in places; in other places the river was dry, except for a few waterholes. However, the settlers state that they have never seen the river so low, and that there is usually a running stream the year round.

At the mouth of Canyon Largo, 3 miles above Sanchez, the valley is about 3,000 feet wide; below the mouth of the Largo the canyon is about 500 feet wide. The bluffs of the second level are 300 feet high; thence the slope is very steep to the first level, which is about 500 feet above the second level. These bluffs are of solid red sandstone. The river bed is sandy. In April the flow was about 5 second-feet.

All the land for about 5 miles above the dam site is cultivated by Mexicans, who have secured patents on their lands. The soil is a sandy loam and is very fertile.

The reconnaissance indicates that a 100-foot dam would store 70,000 acre-feet, cause 1,500 acres to be submerged, and require 335,000 cubic yards of material, and that a 50-foot dam would store 20,000 acre-feet, cause 700 acres to be submerged, and require 64,000 cubic yards of material. In both cases the structure would be of rock, with a 10-foot crown and 1½ to 1 side slope.

A 100-foot dam would back the water 6½ miles up Red River, 3 miles up Mora River, and 5 miles up Largo River. All of these rivers are flowing through a deep canyon averaging 1,500 feet in width. The Mora has a fall of 25 feet per mile, the Largo 15 to 20 feet per mile, and the Red River 16 feet per mile.

Below the dam site the main canyon begins to widen; 3 miles below it is 1 mile wide; then it disappears, the bluffs at right angles to the river developing into high hills; another small canyon is developed, however, varying in depth from 50 to 100 feet, and in width from 100 to 1,500 feet in the first 5 miles.

The red sandstone gradually disappears, grading into a white sandstone. The slope here is very gentle from the river to the bluffs. The land between the Pablo Montoya and the Preston Beck grants is first class, covering about 5 townships, in T. 15 N., Rs. 23 and 24 E., T. 14 N., Rs. 23 and 24 E., and T. 13 N., R. 24 E. But with the data at hand it is plain that it would be impossible to get water upon this land from the only feasible reservoir above it.

At a point 3 miles above the Rio Concha the east bank of the canyon gradually disappears, and finally, at the mouth of the Rio

Concha, changes into low gravel hills, which slope away from the river at the rate of 100 feet per mile. The west bank becomes higher, and farther away from the river changes from white to red sandstone.

About one-half mile below the mouth of La Cienta Creek the river runs through another canyon with high rocky bluffs, similar to that above Sanchez, 1,000 feet above the river; the west bank is of steep gravel hills and the east bank of red sandstone bluffs.

By means of a hand level it was found that a rock dam 100 feet high with 10-foot crown and 1½ to 1 side slopes would contain 325,000 yards of material and would back the water 4 miles up the Cienta and 6 miles up Red River. The reservoir would store 130,000 acre-feet and would have an area of 3,230 acres.

At the dam site the river is 200 feet wide; above it is 300 to 500 feet wide, running on a bed of coarse shifting sand; high watermarks show that it has been 15 feet deep. The drainage area of Red River above this dam is 7,000 square miles, leaving little doubt as to the water supply.

The last-mentioned canyon persists for one-half mile, thence it disappears, developing into a wide valley. The high bluffs are about 2 miles distant on each side of the river; the hills in places are of gravel, and in others of coarse sand covered with gramma grass.

Eight miles below this canyon the river runs into another, varying in width from 800 to 1,500 feet (the river being 300 feet wide), of shifting sand, with side slopes of red sandstone bowlders and gravel averaging 1½ to 1; the first bluffs are 300 feet above the river, thence the land slopes away for one-fourth to one-half a mile to high hills 1,000 feet above the river. A dam could probably be put in anywhere in this canyon.

A survey made with a hand level and a barometer shows that a reservoir with a 100-foot dam at the head of the canyon would store 70,000 acre-feet and cover 2,300 acres.

If a 100-foot rock dam were used, with a 10-foot crown, 1½ to 1 slopes, its yardage would be about 500,000 cubic yards. A 50-foot dam would store 12,000 acre-feet and cover 590 acres; its yardage would be from 30,000 to 50,000 cubic yards. However, as the sides are of solid rock, it might be possible to put in a masonry dam.

Seven miles farther downstream this canyon runs out. It is of solid red sandstone throughout and varies in width from 800 to 1,000 feet. On the south side the river runs against the rock bluffs; on the north side there is an occasional small valley, with steep slopes of sand and gravel and in some places of earth. From this canyon the high mesa on the north side runs northeast for 5 miles, thence north, and on the south side runs due east for 8 miles, thence southwest, following Parjarito Creek. As the valley widens the slope from the river to the hills becomes less. These slopes are very sandy, and are covered with mesquite brush, soapweed, and sand grass. Barometer readings indicate that the average fall of the river below Sanchez is about 100 feet in 6 miles.

The valley of the Pajarito Creek is about 5 miles wide and is of first-class land; most of it has been settled within the last year.

At a point about 5 miles above Tucumcari the creek runs out of a rock canyon which is from 100 to 500 feet in depth and averages 500 feet in width; the bluffs are of solid red sandstone, with sand and gravel slopes to the creek, whose fall averages 35 feet per mile. In sec. 19, T. 11 N., R. 28 E., the valley widens, but has in it a number of small ridges which tend to lessen the capacity of any reservoir above the head of the canyon. Here the fall of the creek is 25 feet per mile. It runs through a wash from 10 to 15 feet deep, the slopes to the hills ranging from 1 in 10 to 1 in 40. The hills on the south side are 1,000 feet and on the north side 800 feet from the creek.

The valley retains this character for 2 miles, then it gradually widens out; 4 miles above the canyon it is 2 miles wide, but owing to the deep washes, ridges, and small hills a dam 50 feet high would store very little water; furthermore, the drainage area above this canyon is but 350 square miles, and includes high foothills but no mountains, hence there is serious question as to water supply.

About one-fourth mile above the canyon there is a spring of good water which runs the year round; at present it is flowing about five-tenths of a second-foot. The land here is red sandy loam, covered with cedar trees and cottonwoods; all of it is settled, mostly by Mexicans.

A lake about 2 miles northeast of Tucumcari, in secs. 12, 13, and 24, T. 11 N., R. 30 E., is 3 miles long and 1½ to 2 miles wide; it has no outlet. The drainage into this lake is 10 square miles; it has never been more than 1 or 2 feet deep. Its greatest possible depth would be 25 feet. Because of a long, low ridge on the northwest side of the lake a fill at least one-half mile long would be required to increase its capacity

The main line of the Chicago, Rock Island and El Paso Railroad and the new roadbed of the Choctaw, Oklahoma and Gulf Railroad pass through this lake, and about one-half mile of each road would be submerged if it were filled. Furthermore, owing to the high ridges on the north, south, and east of this lake, the only land that could possibly be irrigated would be about 4,000 acres in Parjarito Creek Valley. To get water on the land below this would require about 20 miles of rock cut through the cliffs of the Parjarito and Red rivers, ending in Red River Valley.

Largo Valley is 5 to 8 miles wide, the soil is a first-class sandy loam, covered with a thick growth of sand grass. Here water is obtained at a depth of 20 to 30 feet, and in a few places fresh-water springs run into the creek, but owing to the sandy bottom the water sinks. It was thought possible to store water above this valley, but this valley is in reality the head of Largo Creek. The drainage above it is about 100 square miles, divided among three small creeks, draining only high hills. The average fall of the creeks is 15 feet per mile.

In sec. 16, T. 10 N., R. 30 E., the creek runs into a rock canyon 30 feet deep and 200 feet wide; this canyon gradually deepens to 150 feet, and is 500 feet wide at its mouth. To get the water out of it, if dammed at its head, would require 6 or 8 miles of rock cut in white sandstone, an expenditure which is not considered warranted.

Three miles from Tucumcari, Parjarito Valley becomes narrow; there are steep slopes to high hills on each side, covered with red sandstone gravel and solid sandstone bluffs; it continues the same to its mouth. The creek was dry, but there are large floods in the spring.

Three miles below the mouth of Parjarito Creek Red River runs into a canyon of gray sandstone, varying from 200 to 800 feet in width and from 100 to 200 feet in depth, and remains in it to and beyond the Texas line.

A reconnaissance of a canal line from La Cienta dam site was made, and it was found that the first 30 miles of canal would irrigate no land, and that 7 miles of this would be through solid rock canyons. However, at the mouth of the canyon, near the SE. corner of T. 13 N., R. 28 E., a diversion dam could be built that would save 15 miles of this canal. In the balance of the canal there would be little or no rock cut.

The first 60 miles of the canal on the south side of the river would irrigate 75,000 acres and the first 60 miles on the north side about 100,000 acres of good land. If the canals were longer, the number of irrigable acres per mile would increase.

INVESTIGATIONS IN PECOS VALLEY.

ARTESIAN WATER.

Many requests have been made that Pecos Valley be examined for the purpose of determining the source of artesian water, the approximate area that will afford an artesian flow, and any other information that might aid those now using this kind of water or contemplating using it in the future.

In compliance with these various requests, C. A. Fisher, assistant geologist, was detailed to take up the work in the valley. His report is printed on pages 414–419.

Mr. Fisher spent some time studying the geology of the area where artesian water has been obtained and also of the district to the west, which is mountainous and possibly the source of supply. The gathering of other information has been undertaken by members of the Reclamation Service, who have run levels from the water level at the head of North Spring River southward as far as Seven Rivers, covering the probable artesian belt. The water level at the head of North Spring River seems to be the limit of height to which the artesian water will rise.

The Reclamation Service is also taking monthly pressure measurements of several of the most prominent artesian wells.

LAKE McMILLAN.

SILT SURVEY ON PECOS RIVER.

INTRODUCTION.

Pecos River rises in north-central New Mexico, on the east side of the Santa Fe Range. For some distance it is a typical mountain stream, flowing with swift current through rocky canyons. It is perennial until after it crosses the line of the Atchison, Topeka and Santa Fe Railroad. Farther down, during dry periods, it entirely disappears, being lost by evaporation and by percolation into the porous rocks; but from Santa Rosa, on the Rock Island Railroad, where it is fed by springs, it has a constant flow to a point 40 miles below old Fort Sumner, where, during extremely dry periods, it again entirely disappears. At a point 15 miles above Roswell it receives the flow of springs from the west side and is a perennial stream from that point to its junction with the Rio Grande in western Texas.

The silt conditions in the upper valley are not serious. The silt consists of nothing more than the material ground away by the mountain torrents and soon settles, often before reaching the main channel. Lower down on the river, where the course is through alluvial soil, more silt is gathered, until at the McMillan reservoir the water is heavily charged, and the problem of disposal of the silt must be carefully considered when storage reservoirs are contemplated. It is evident that very little thought was given to silt conditions when the McMillan reservoir was constructed, as no means of relief were provided.

GEOLOGIC CONDITIONS.

The course of the Pecos in Chaves and Eddy counties is through a limestone formation. Large deposits of gypsum are to be found along its course, particularly on the east side of the river. Where the drainage waters from the east enter the river bottom, the canyons often show large bodies of gypsum, which in some places is capped with a firm limestone and in some places is exposed at the surface. Deep artesian wells, sunk in Chaves and in the northern part of Eddy County along and adjacent to the river bottoms, have encountered no body of gypsum; yet as gypsum is found in many places on the west side of the river and farther away—though rarely exposed—it is probable that it once extended entirely across the valley, but by the action of the water has been dissolved and carried away. The silt from the river has covered up the gypsum, where it does exist, and for miles at a time there is no perceptible loss; but should the water be checked and backed up to any considerable extent it often encounters the gypsum on the side.

LAKE McMILLAN RESERVOIR.

Lake McMillan is the principal storage reservoir of the irrigation system owned and operated by the Pecos Irrigation Company, whose principal office is at Carlsbad, N. Mex.

This reservoir was visited by the supervising and consulting engineers of the Reclamation Service during the winter of 1903–4, and so many interesting features were noted that instructions were issued to the district engineer to make a careful study of the conditions.

The drought of 1903 continued into the summer of 1904, and in June of this year the reservoir was found to be practically empty. It was realized that this condition would probably not last long, and a force of seven men was therefore put to work to obtain the desired data. Work was begun on June 1, 1904, and was brought to an end on June 15 by water coming down the river and closing all work. Although some desired data were not obtained, sufficient information was procured, it is thought, to make the report serviceable to those who may find similar conditions elsewhere; so that it may aid in solving the great reclamation problems of the West.

THE DAM.

The site chosen for the dam was at a point where the limestone bluffs approached very closely from opposite sides of the river. No gypsum was exposed at the time of the construction, nor has any appeared since at this point, but there is now a hole in the bottom of the reservoir 400 feet above the dam. When the water is low this can be detected, and has the appearance of causing considerable loss by leakage. The opening converges toward its bottom and seems to end in a seam in limestone. The fact that it has not increased to a large opening would seem to indicate that if gypsum does exist at this point it is capped by a less soluble limestone. A number of holes of this character occur at various points within the reservoir site, and those that occur away from the edge appear to be of the same nature.

Along the east side, next to the high bluffs, there is a long stretch of gypsum capped with many feet of limestone. It is quite probable that at the time the reservoir was constructed the gypsum was covered with earth and was not visible. But when the water was raised to this height the percolation, aided by the wave action, swept the surface clear, so that for a long distance the gypsum is now exposed and is the cause of an immense amount of leakage.

The dam is of the rock-fill earth-apron type and is constructed across the channel of the Pecos, forming the reservoir in the channel and valley of the river. It was completed during the winter of 1893–94 and has been in continuous operation since that time. It has a top length of 1,686 feet and a maximum height of 52 feet, with an auxiliary embankment 5,200 feet in length and with a maximum height of 18.8 feet across a low place to the west. This embankment is built entirely of earth, being protected on the water side for about one-third of its height by riprap 1 foot in thickness. The rock-fill portion of the dam is 14 feet wide at the top and the earth 6 feet, making a total top width of 20 feet. The slopes are rock fill, 1½ to 1 on lower side and one-half to 1 on upper side, which latter is a dry-laid wall. The earth apron has a slope of 3½ to 1 and is covered for its entire height with riprap 1 foot in thickness. With the water 7 feet below the crest of the dams, the capacity of the reservoir was a little over 100,000 acre-feet.

Since the completion of the dam during the winter of 1893–94 the silting process has been going on, and as this survey was made in 1904, prior to any rise of importance in the river, the results can be figured on the basis of a ten-year period.

OUTLET CANAL.

The outlet for the reservoir is through a rock canal to the east of the dam, which is controlled by a system of six wooden gates operated by screws. It has a combined discharge of 6,000 second-feet when the water is at its proposed maximum height.

SPILLWAYS.

A spillway was provided between the outlet canal and the dam proper. This spillway was constructed by making a cut about 200 feet in width into the natural surface, which was composed of a soft lime rock interspersed with many layers of earth. A short time after the reservoir was built this spillway was seen to be a source of danger; the water would have been returned to the river at a point near the lower toe of the dam and the backwash would have endangered the structure. In addition the material was so soft that the sides of the spillway would have been cut away and serious damage would have resulted to the gates. Also, the capacity of the reservoir would have been very materially decreased. The spillway was blocked very soon after the structure was completed and a safety, or emergency, spillway was cut in the embankment, farther west. This second spillway was blown out by explosives during a period of high water, at a time when the face of the dam showed a settlement that seemed very dangerous. Later the section was reduced to the natural surface, thereby doing away with the storage that was due to a mile of embankment, no portion of which was replaced until the winter of 1903-4.

This channel was used for a spillway for the surplus water for ten years. The waters that passed here did not reach the river for 2 miles, and although they began cutting back, the effect did not reach the reservoir until 1903. The channel was entirely in earth, and each year the cut-back approached nearer the main reservoir, and for the past three or four years the irrigation company has known that another spillway of more permanent nature must be provided.

During the floods of June, 1903, when a large amount of water passed over this spillway, in spite of the fact that the gates were used to their fullest extent, the cut-back reached almost to the reservoir proper and made a change absolutely necessary.

This change was accomplished by blocking the opening with an earth fill and cutting another opening farther east, through the rock, at an elevation 6 feet higher than the old spillway, apparently increasing the storage capacity about 13 per cent. The real increase will be discussed later.

The new spillway is cut through a limestone foundation, and is of such a nature that should it be subjected to a heavy flood for a long time it would be greatly eroded, but it is probable that it will not be required to carry a very large flow for any considerable length of time.

CAPACITY.

There are no old data available from which to calculate the capacity of the reservoir after the earth embankment to the west was cut away to the natural surface, and the facts concerning this are to be obtained only from the survey made in June last by the Geological Survey—a survey which is of more or less doubtful accuracy, as the original surface had to be determined by borings and there were several feet of silt deposit, making mistakes easy as to the exact location of the old bed. However, great care was exercised, and it is believed that the results give a very accurate idea of the condition as it exists to-day.

By these surveys it is determined that the capacity of the reservoir up to the earth spillway that marked its limit until the present year, before any silt was deposited, was 32,542 acre-feet.

Curves have been platted showing the area submerged and the capacity of the reservoir for the various heights above sea level, and have been adjusted to the height on the gage rod maintained at the head-gates by the Pecos Irrigation Company. A daily record of these heights is kept. The curve for the area will remain correct for some time, but the curve for the capacity will change with each flood.

SILT.

In order to determine the amount of silt already deposited, numerous borings were made over the exposed bottom of the reservoir and located by use of the plane table. Ordinary screw post-hole diggers supplied with extension shanks were used to make the borings, and the natural surface beneath the silt was determined by the change of color in the material and also by the particles of vegetable matter found in most places where the natural surface was reached. Diagrams of the reservoir at the time of the silt survey are given on Pl. XLV.

Before the reservoir was constructed the surface of the ground almost to the edge of the water in the river was covered with a very heavy growth of salt grass, which is still sufficiently preserved to afford reliable data as to the position of the original surface. In some places no trace of this was found, and it was thought that at such localities either the old river bed had been encountered or a spot made barren by some unknown cause had existed. By careful observations the old bed of the river was traced over a portion of the bottom.

The points for the borings were determined by running a series of parallel east-west lines at a distance of one-fourth mile apart. No measuring was done on these lines, which were run with a transit and marked with small flags to enable the workmen to keep in line. A boring was made every 100 paces along these lines. Each line was indicated by a letter of the alphabet, and each workman was supplied with a book and pencil for recording the depth to the natural surface and any item of interest that might develop. He was also supplied with short pieces of lath, one of which he set at each finished hole, with the line letter and the number of the boring on the line marked upon it, so that when located it could be studied from the record kept in the notebook.

The laborers for this work were chosen for their faithfulness and intelligence, and after careful instructions and inspection for a short time were allowed to proceed with an occasional inspection while the level and topographic party were carrying out their work.

A base line 5,000 feet in length was laid off on the west side of the reservoir and carefully measured. At each end a galvanized pipe 3 inches in diameter and 3 feet in length was driven into the ground and protected by limestone rocks piled around it.

The triangulation points were marked in the same manner, the sections of pipe marking those on the west side being so set in the ground that only six inches of the pipe was above the surface. Around each pipe is a monument of rock.

On the east side it was not possible to get the sections of pipe into the rock to so great a depth, and larger monuments of rock were used as a means of protection.

Pipe at station A is marked with a cold chisel thus: "U.S.G.S." The other stations have no marking on them.

In addition to locating the contour lines, the topographic party used great care in locating all holes and places indicating possible leaks, both in the bottom of the site and along the edges. These openings in the bottom of the reservoir all show a porous and much seamed limestone at bottom. It is possible that beneath this limestone is a stratum of gypsum, but the holes do not seem to be increasing very rapidly in size and there is no doubt that they could all be permanently closed at a very small expense. If there is any kind of coarse, pliable material in the bottom the silt that is everywhere present could be used to permanently seal them.

The leaks around the perimeter are of a different nature; the points marked on the topographic sheets, on the east side, indicate only the deep and well-defined holes; the material here is gypsum, and has been washed and dissolved by the water until it takes fantastic shapes. In some places it is covered with silt, but even here, when it dries, cracks appear that extend back into the hills.

When the water reaches this formation it flows in bold streams into the openings, and sections covering several thousand square feet have dropped down, in some places 5 or 6 feet.

By looking down the cracks at the edge of these sinks water can be seen flowing in them with a high velocity. The general course of this flow seems to be southeast, directly back under the high hills. Where it goes is yet an unanswered question, although some light is shed upon this question by measurements and investigations conducted by Mr. V. L. Sullivan, engineer for the Pecos Irrigation Company, a synopsis of which will be given later.

A few random borings taken at a considerable distance above the highest storage contour showed the depth of silt to be greater there than at any point within the storage area. When the reservoir is full to the spilling point and the river comes down in flood, the moment the flood meets the still water the velocity is reduced and the heavier silt at once deposits. The heavier silt, which is almost a pure sand, is found at the upper end of the deposits, as it is the first material to settle when the velocity of the current is reduced.

It would be interesting to determine what proportion of the entire silt deposits lay outside the storage area, but this determination was impossible at this time, owing to the high water in the river and the flooding of the whole area; yet from the random borings taken and the apparent area it is certain that a large percentage of the silt, especially the heavier variety, is deposited entirely outside the storage area. It was found by calculations from cross sections taken of the silt that there was at the time of the survey 12,232 acre-feet of silt within 3,260-foot contour.

The height at which the reservoir spilled previous to the work of last winter was 17.3 feet on the gage rod, or at the 3,259-foot contour. The capacity at this height, taken from the capacity curve, is found to be 16,500 acre-feet. This would have made the capacity 28,732 acre-feet before silting up began. This indicates that during a period of ten years the available capacity has been reduced by the silting-up process about 42 per cent, or an average of a little more than 4 per cent per annum.

Some interesting comparisons and calculations can be made upon this silt question by referring to Principles of Water Analysis as Applied to New Mexico Waters, by Prof. Arthur Goss.[a]

In this bulletin Professor Goss treats not only of the chemical constituents of the waters of New Mexico, but gives also the figures of suspended matter found in the principal rivers of the Territory. On pages 73 and 74 he treats of Pecos River. Samples taken from various points on the river are mentioned, but only those taken from above Lake McMillan would be of any value in determining anything concerning the silt deposit in Lake McMillan.

Samples from this point show as low as 36 and as high as 563 parts of suspended matter in 100,000 parts of water.

The records of the flow of the Pecos near Roswell, obtained by work done during the last eighteen months by the United States Geological Survey to determine the proportion of flood flow carrying the highest per cent of silt and the flow carrying the minimum, show that 300 parts per 100,000 is about the average.

If then, 0.003 is the average per cent of silt carried, and if 0.042 per cent is the average yearly deposit, the reservoir has had to fill 14 times each year in order to receive the amount of silt that has been deposited within the storage area.

The capacity of the reservoir began with 28,732 acre-feet, and at the end of ten years is found to be 16,500 acre-feet. This would give an average of 22,616 acre-feet of silt per annum. This multiplied by 14 gives 316,624 acre-feet as the average quantity of silt that must have accumulated within the storage area of the reservoir each year in order to aggregate the amount it now contains.

This does not take into consideration the amount of water that must have passed in order to deposit the silt that is found outside the storage area. While sufficient data were not obtained to calculate this amount of silt, it is considerable, and, judging from the great depth at the upper end of the lake, might run as high as a 50 per cent increase.

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[a] Bulletin No. 34 of the New Mexico college of agriculture and mechanical arts.

The total flow of the Pecos near Roswell for the year ending April 30, 1904, was 338,000 acre-feet, the lowest annual flow known to old settlers familiar with the Pecos. The average flow of the river is undoubtedly much more than this, and as more data become available it will be interesting to study the relation between the suspended matter in the water, as determined by Professor Goss, and the actual amount of silt deposited within and about the reservoir. The survey made in June established points that are sufficiently permanent to be used at some future time in carrying on further investigations of this question.

LEAKAGE AT LAKE M'MILLAN.

The fact that there is loss by leakage through the gypsum formation has been well known almost from the time of the establishment of this reservoir, but the amount of this leakage was unknown, and until recently no attempt was made to determine this point.

Some attention was paid to this important question when the silt survey was undertaken, and later in the season the problem of loss was taken up and studied to the extent of utilizing all available data.

Mr. V. L. Sullivan, engineer for the Pecos Irrigation Company, had undertaken some investigations to determine what part of the water lost from Lake McMillan found its way back to Pecos River above Lake Avalon and was available for use in the irrigation system. Upon request Mr. Sullivan furnished the following report of his work:

> We emptied Lake McMillan last year on August 22, and on August 31 I measured Pecos River above Lake McMillan reservoir and found the flow to be 49.55 second-feet. In order to make sure of a constant flow of the river I measured it again at the same place on September 12 and found the flow to be 48.80 second-feet.
>
> During this time the gates at both reservoirs were opened high in order to allow river water to flow by unobstructed.
>
> On September 8 I measured the water in the canal below Lake Avalon and found the flow to be 62.94 second-feet, making an increase of 14.24 second-feet between Lake McMillan reservoir and the canal, due to constant springs, as Lake McMillan reservoir had been emptied for about seventeen days.
>
> This year we did not open Lake McMillan gates until April 16, and we commenced using water from Lake Avalon reservoir on February 2. We used water for irrigation about two and one-half months before it was necessary to open the gates at Lake McMillan reservoir.
>
> The water was practically below the leaks in McMillan reservoir by that time, and Lake Avalon had commenced to fall very fast.
>
> With 17 feet or more of water in McMillan reservoir, gates closed, we used about 125 second-feet of water from Lake Avalon reservoir and still kept Lake Avalon nearly constant, showing that we must get about 125 second-feet of water that we used minus the 14 second-feet of water from constant springs

between the reservoirs, or about 111 second-feet of water caught in the lower reservoir from the leaks in McMillan reservoir when it contains 17 feet or more of water.

The water in the McMillan reservoir was not stationary at 17 feet, but was falling, and the above estimates were made by careful observations and measurements at the most suitable times.

I am inclined to believe from observations that it takes a couple of weeks or more for the water to appear in Lake Avalon after it reaches the first general leaks in Lake McMillan, but the supply diminishes in Lake Avalon nearly as fast as the water goes down in McMillan reservoir.

The investigations made by Mr. Sullivan indicate that a portion of the water that passes off through the gypsum and apparently into the hills is returned to the river before it reaches Lake Avalon; in other words, that there is a subterranean reservoir, which can not be controlled, but which affords some supply for use upon the lands under this irrigation system.

These investigations, while showing conclusively that some of McMillan's escaping water does return in time for beneficial use, did not go far enough to show whether it all returned or what portion was returned and became available and what portion was lost to usefulness under this system.

To obtain more information upon this point facts were obtained and calculations made as follows:

It was known that for many years the Pecos Irrigation Company had kept a daily record of the gage heights at their reservoirs, and a copy of these records was obtained from the engineer's office.

During the work of the silt survey the datum of the gage had been adjusted to the sea-level elevations used in the survey, and the capacity and acreage curves gave the capacity in acre-feet and acreage submerged for each gage reading.

Following are portions of the records for the months of June, 1903, and March, 1904, of the gage heights at the two reservoirs, McMillan and Avalon. The columns marked "Head," "Velocity," "Coefficient," and "Discharge" are not part of the company's record, but were supplied by the Geological Survey:

Discharge, in second-feet, of Lake McMillan in June, 1903.

Day.	Reservoir height.		Number of gates open.	Opening each gate.	Total vertical opening.	Head.		Theoretical velocity.	Coefficient.	Discharge.
	Ft.	*in.*		*Inches.*	*Inches.*	*Ft.*	*in.*		*Per cent.*	*Sec. ft.*
1	15	3	4	9	36	14	10½	30.85	69	255.4
2	15	1	4	9	36	14	8½	30.70	69	254.2
3	14	10	4	9	36	14	5½	30.50	69	252.5
4	14	9	4	9	36	14	4½	30.37	69	251.4
5	14	7	4	9	36	14	2½	30.20	69	250.0
6	14	5	4	9	36	14	½	30.00	69	248.4
7	14	1	4	9	36	13	10½	29.87	69	247.3
8	13	10	4	10½	42	13	4¾	29.37	69	283.7
9	13	7	4	10½	42	13	1¾	29.00	69	280.1
10	13	8	4	10½	42	13	2¾	29.20	69	282.1
11	15	0	6	4	24	14	10	30.10	69	166.1
12	17	6	6	12	72	17		33.10	69	548.1
13	19	4	6	12	72	18	10	34.10	69	564.7
14	18	6	6	12	72	18		34.00	69	563.0
15	17	6	6	12	72	17		33.10	69	548.1
16	17	1	6	12	72	16	7	32.70	69	541.5
17	17	0	6	12	72	16	6	32.60	69	539.9
18	17	1	6	14	84	16	6	32.60	69	629.8
19	18	6	6	14	84	17	11	33.92	69	655.1
20	18	0	6	14	84	17	5	33.50	69	647.2
21	17	2	6	14	84	16	7	32.70	69	631.8
22	16	2	6	14	84	15	7	31.70	69	612.4
23	15	8	6	10	60	15	3	31.35	69	432.6
24	15	0	6	8	48	14	8	30.70	69	339.0
25	14	6	6	7	42	14	2½	30.20	69	291.7
26	13	11	6	7	42	13	7½	29.62	69	286.1
27	13	4	6	7	42	13	½	28.90	69	279.2
28	13	4	6	12	72	12	10	27.90	69	462.0
29	13	7	6	12	72	13	1	29.00	69	480.2
30	13	1	6	12	72	12	7	28.50	69	472.0
Mean.										[a] 409.9

[a] Equal to 24,391 acre-feet.

0 of gage rod = elevation 3,241.4 of U. S. G. S. survey 1904.

Height of Lake McMillan in March, 1904.[a]

Day.	Reservoir height.		Day.	Reservoir height.		Day.	Reservoir height.		Day.	Reservoir height.		Day.	Reservoir height.		Day.	Reservoir height.	
	Ft.	*in.*		*Ft.*	*in*		*Ft.*	*in.*		*Ft.*	*in.*		*Ft.*	*in.*		*Ft.*	*in.*
1	17	4	7	17	2	12	16	11	17	16	2	22	15	9	27	15	4
2	17	3	8	17	2	13	16	8	18	16	1	23	15	8	28	15	5
3	17	3	9	17	1	14	16	6	19	16	0	24	15	7	29	15	2
4	17	3	10	17	1	15	16	5	20	15	11	25	15	6	30	15	1
5	17	3	11	17	0	16	16	4	21	15	10	26	15	5	31	15	1
6	17	3															

[a] All gates closed.

Discharge, in second-feet, of Lake Avalon in March, 1904.

Day.	Reservoir height.		Number of gates open.	Opening each gate.	Total vertical opening.	Head.		Theoretical velocity.	Coefficient.	Discharge.
	Ft.	*in.*		*Inches.*	*Inches.*	*Ft.*	*in.*		*Per cent.*	*Sec. ft.*
1	18	1	4	4½	18	17	11	33.9	69	117.0
2	18	½	4	4½	18	17	10	33.8	....	116.9
3	18	0	4	5¼	21	17	9½	33.8	....	136.0
4	17	11	4	5¼	21	17	8½	33.7	....	135.5
5	17	9	4	5¼	21	17	6½	33.6	....	135.0
6	17	9	4	5¼	21	17	6½	33.6	....	135.0
7	17	8	4	5¼	21	17	5½	33.6	....	135.0
8	17	0	4	5¼	21	16	9½	32.9	....	132.0
9	17	6	4	5¼	21	17	3½	33.4	....	134.0
10	17	6	4	4½	18	17	4	33.4	....	115.5
11	17	6	4	4½	18	17	4	33.4	....	115.5
12	17	6	4	4½	18	17	4	33.4	....	115.5
13	17	5	5	4	20	17	3	33.3	....	127.8
14	17	4	5	4⅕	21	17	2	33.2	....	133.0
15	17	3	5	4⅕	21	17	1	33.2	....	133.0
16	17	3	5	4⅕	21	17	1	33.1	....	133.0
17	17	2	5	4⅕	21	17	0	33.1	....	133.0
18	17	1	5	4⅕	21	16	11	33.0	....	132.5
19	17	1	5	4⅕	21	16	11	33.0	....	132.5
20	17	1	5	4⅕	21	16	11	33.0	....	132.5
21	17	1	5	4⅖	22	16	11	33.0	....	139.0
22	17	0	5	4⅖	22	16	10	32.9	....	138.8
23	16	11	5	4⅖	22	16	9½	32.8	....	138.0
24	16	10	5	4⅘	24	16	7½	32.7	....	150.5
25	16	9	5	4⅘	24	16	6½	32.6	....	150.0
26	16	8	5	4⅘	24	16	5½	32.6	....	150.0
27	16	7	5	4⅘	24	16	4½	32.5	....	149.5
28	16	5	5	4⅘	24	16	2½	32.3	....	148.8
29	16	3	5	4⅘	24	16	½	32.1	....	147.5
30	16	2	5	4⅘	24	15	11½	32.1	....	147.5
31	16	1	5	4⅘	24	15	10½	32.0	....	147.0
Mean.	....		....	....	....	....		....	....	135.1

[a] Equal to 8,307 acre-feet.

Pecos River was measured March 22, 1904, by V. L. Sullivan, 6 miles north of McMillan station, and was found to be 86.48 second-feet.

The month of March was chosen for the purpose of determining the loss because the gates at McMillan were not opened during this month and no water escaped except by evaporation and leakage.

The Department of Agriculture maintained a station at McMillan for one year for the purpose of determining the evaporation, and from these records it was considered that 3 inches was a fair amount to allow.

At Avalon the gates were open during the entire month and the conditions were such that a fairly accurate calculation could be made of the flow through the gates.

On March 22 Pecos River was measured above Lake McMillan by Mr. Sullivan, the irrigation company's engineer, and found to be discharging 86.48 second-feet, or 171.5 acre-feet per twenty-four hours. The gage at this reservoir, as recorded, shows a uniform fall of the water in the reservoir of 1 inch a day, extending over a period of several days each way from the 22d.

The gage read 15 feet 9 inches on March 22 and 15 feet 8 inches on March 23. By referring to the acreage and capacity curves it is found that the acreage submerged when the gage reads 15 feet 9 inches is 2,700 acres. The water having fallen 1 inch over this entire area gives a total loss of 225 acre-feet for the twenty-four hours, March 22 to March 23. As this is the time of equinoctial storms and as it is possible that high winds may have prevailed, an allowance of one-fourth inch for evaporation was made, making the total loss due to evaporation 56¼ acre-feet, and leaving a loss of 168.75 acre-feet due to other causes.

Besides this loss of 168.75 acre-feet of water already stored there was supplied from the river flow 171.5 acre-feet, which was also lost, making a total for the twenty-four hours between March 22 and March 23 of 340.25 acre-feet. For the month of thirty-one days, even allowing the high evaporation of one-fourth inch a day, or 7¾ inches for the month, which is excessive, the loss from leakage from this reservoir would be 10,547 acre-feet.

Another calculation to determine the loss can be made as follows: The gage height read 17 feet 4 inches on March 1, and 15 feet 1 inch on March 31. From the capacity curve it will be seen that on March 1 there were stored 16,750 acre-feet and on March 31 11,500 acre-feet, making the loss from storage during this period 5,250 acre-feet.

The gaging station at Roswell, N. Mex., shows that there was an average of 10 per cent more water during the month than was found in the river from March 19 to March 24. This would make the amount for the month furnished by the river 5,848 acre-feet, making the total loss 11,098 acre-feet. From this can be deducted the evaporation of 3 inches over the average surface exposed during the month (2,850 acres), which equals 712.5 acre-feet. This gives the loss due to leakage as 10,386 acre-feet.

The next calculation is for the purpose of determining what part of this water returns to the river in time to be available in the irrigation canals.

The discharge through the gates at Lake Avalon was calculated as 8,304 acre-feet during the month of March. Assuming that Mr. Sullivan's calculations for the discharge of the natural springs between Lake McMillan and Lake Avalon are correct, we have a daily supply of 14.14 second-feet, making the monthly supply from this source 869.45 acre-feet. The average area of Avalon for this month is shown by existing maps to be 1,500 acres. With 3 inches of evaporation, the loss from this source would be 375 acre-feet.

The gage height read 2 feet lower at the end of the month than at the beginning, which would give a loss from storage of 3,000 acre-feet. We have, then, as follows:

Estimated loss by evaporation at Lake McMillan.

	Acre-feet.
Water drawn into the canals	8,304
Water drawn off by evaporation	375
Water leaving reservoir and accounted for	8,679
Water supplied by natural springs	869
Water supplied from previous storage	3,000
Water supplied and accounted for	3,869
Water supplied and not accounted for	4,810

It is reasonable to suppose from the above records and calculations that this 4,810 acre-feet came from the water lost from Lake McMillan, but during the same time the loss from McMillan was 10,548 acre-feet, which indicates that the absolute loss from Lake McMillan was 5,738 acre-feet for the month of March.

It is possible that some more water lost from Lake McMillan was caught in the river above Avalon and again lost by leakage from Avalon, but this amount is probably small as compared with the loss from McMillan, for while the formation at Avalon is limestone it is in more regular and closer-fitting layers, less liable to leakage, and there are no indications of the existence of gypsum about this reservoir.

It is very evident that a greater loss takes place after the water reaches the gage height of 17 feet. The perceptible leakage channels are nearly all at or above this level and the silt has become so thoroughly distributed over the bottom that if leakage ever existed it has now been sealed by this material. The few remaining places in the bottom could be easily sealed when the water is low by very little labor or expense.

Leakage on the perimeter, where so much gypsum is exposed, can probably be prevented, but whether the benefits to be derived would justify this additional expense will not be considered here.

CONCLUSIONS.

As a result of these investigations it appears that questions concerning the storage of waters heavily laden with silt must necessarily call for very careful investigations and in all cases it must be known whether the results will justify the expenditures.

Another lesson taught is that when gypsum is known to be present in the vicinity of a proposed storage reservoir, great care should be exercised in determining whether any gypsum exists about the site and whether it is so situated that it can become a channel for conveying water to districts unknown.

LA PLATA VALLEY PROJECT.[a]

The La Plata project (Pl. XLVI) is located along the north side of San Juan River, in San Juan County, in northwestern New Mexico, the greater part of the land to be cultivated lying along La Plata River, a tributary of the San Juan.

The water supply for this project will be derived mainly from Animas River.

It is planned to make diversions from Animas River, in Colorado, 3 miles above the town of Durango, and to convey the water to lands lying in and along La Plata Valley by means of canals aggregating in length approximately 100 miles, including distributing canals, and a tunnel 2 miles in length through the high ridge between Animas and La Plata rivers.

To make this project successful it will be necessary to supplement the low-water flow in Animas River during a considerable portion of the irrigating season by storage, both at the head of La Plata Valley and on Animas River. For this purpose there is an abundance of water during high-water stages.

The project contemplates the reclamation of approximately 50,000 acres of land. In all, 15 townships lying in and near the La Plata and Animas River valleys have been withdrawn, aggregating approximately 308,736 acres; also 4½ townships lying in Colorado along Animas River, embracing approximately 80,640 acres. These are held under the first form of withdrawal pending future examinations, withdrawal having been requested under dates of August 8 and 15.

A preliminary investigation was made between June 14 and 24, 1904. It consisted of a reconnaissance over a portion of the lands to be watered and along a portion of the proposed canal line, together with the collection of data concerning lands, crops, water supply, storage facilities, etc. This was followed by preliminary surveys.

A reconnaissance of the drainage basin of Florida River, from its headwaters nearly to the Colorado-New Mexico line, was made in August for the purpose of locating storage reservoirs. No feasible site was discovered, however.

Bishop Lakes, lying north of Durango and west of Animas River, were also investigated for the purpose of determining their utility for storage purposes, but it was discovered that these sites had already

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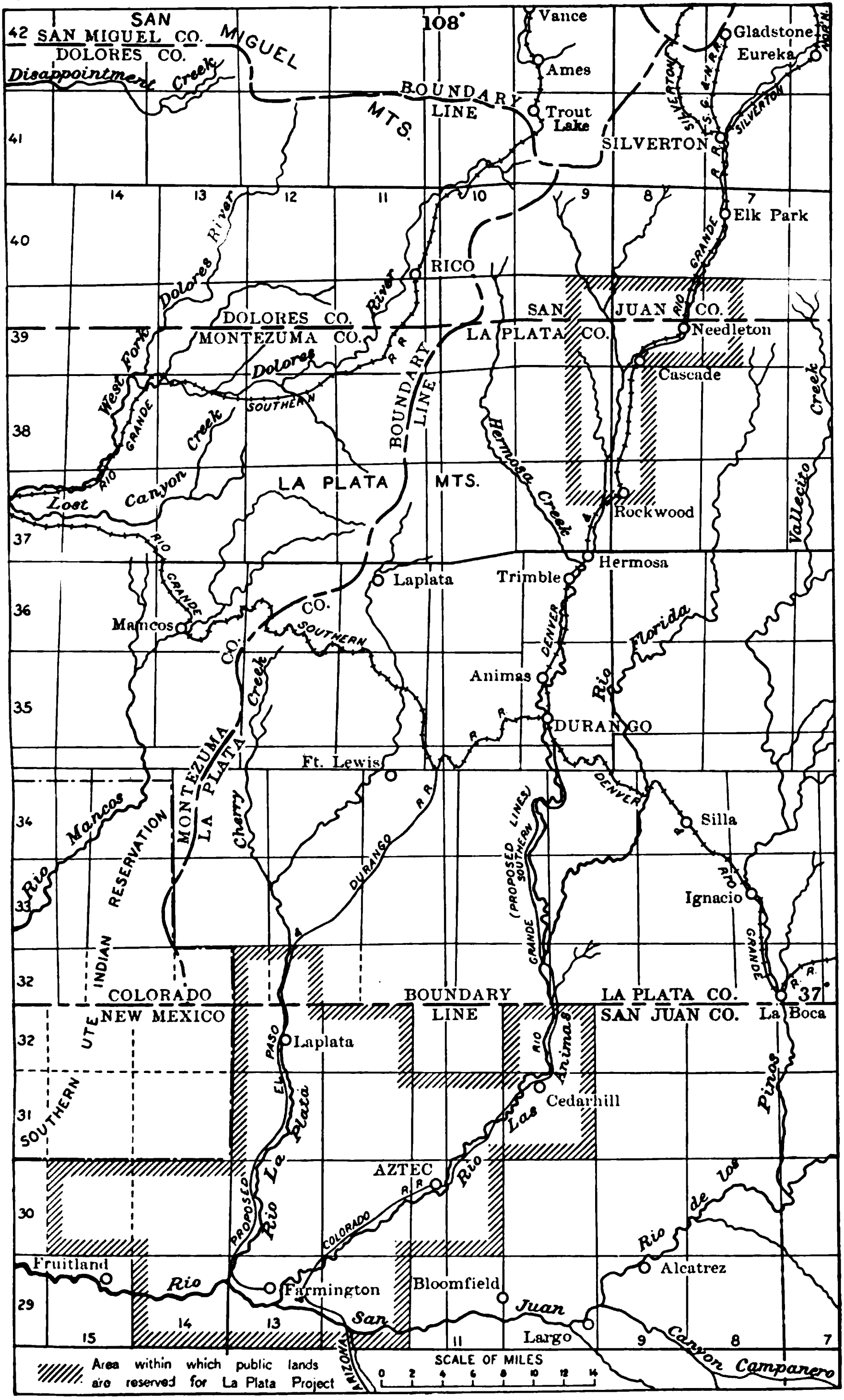
[a] From report by M. C. Hinderlider.



GENERAL MAP OF PROPOSED LA PLATA VALLEY PROJECT, COLORADO-NEW MEXICO.

been filed upon and were being developed by a local corporation for power purposes.

Actual work in connection with preliminary surveys was commenced September 20, when a party under the direction of M. C. Hinderlider, engineer, left Durango, Colo., for New Mexico. Two days later a field party, under direction of Theodore Tobish, was established at Navajo Springs; and a second party, in charge of E. L. Shinbur, was located at the narrows or dam site at the upper end of the meadows west of La Plata River.

All the first-class irrigable land of the meadows has now been surveyed and the acreage computed. The main arroyo running through this tract of land has been meandered and a level line carried along it for the purpose of locating the acreage lying on either side. All the first-class irrigable lands in the McDermith Glade and those in and west of La Plata Valley have also been surveyed and the acreage has been computed.

The triangulation and the topography of the reservoir and dam site at the head of the meadows has been completed, the reservoir site being developed on a scale of 500 feet to 1 inch, with 5-foot contours, and the dam site on a scale of 50 feet to the inch, with 2-foot contours.

In addition, the vertical control has been carried from the meadows reservoir site to the reservoir site on La Plata River, a distance of 13.5 miles, by two level parties, one checking on the other, and a 5,000-foot base measured, and the primary triangulation between the meadows and La Plata River taken up and completed.

The primary location of the canal between the reservoir site on the La Plata and the one at the head of the meadows has been completed, and a line of levels run over it to secure a profile. This location required more than ordinary care, owing to the necessity of providing for suitable drops.

The topography along the line has been completed on a scale of 100 feet to an inch, with 5-foot contours. At the points where the drops occur the contours were taken every 2 feet.

The topography of the reservoir site on the La Plata River has been mapped on a scale of 400 feet to an inch, with 5-foot contour interval, and that of the dam site on a scale of 50 feet to an inch, with 2-foot contour interval.

Two fly lines were run eastward from the reservoir site on La Plata River toward Animas River for the purpose of locating a line for the main diversion canal. These lines, with further reconnaissance, demonstrated the impracticability of such a route, but developed the possibility of an extremely high line, which, however, could have but one course or location.

The preliminary survey of this line was immediately taken up, and was in progress at the close of the year, when one-half of this line had been located and the topography started. The triangulation for the topography of the large reservoir site on Animas River had also been completed. It is expected that all field work in connection with the preliminary work on this project will be completed by March 31, 1905.

RECONNAISSANCE ALONG UTE CREEK.[a]

The Ute Creek reservoir site, which is located about 8 miles northwest of Logan, N. Mex., at a bend of Ute Creek, was investigated during the past summer by W. G. Russell, hydrographer, who found that the waters of a reservoir constructed there would be too low to reach any considerable body of the lands near Logan, which is 140 feet above the bed of Canadian River. Other objections were the lowness of the dam site, especially on the left bank, where it has only 50 feet elevation when the width is one-half mile, and the fact that the bed of the stream and the bottom lands are sand, making dam construction expensive and uncertain.

The bed of the creek and up to 50 feet of elevation on the left bank were cross-sectioned, but it was not thought advisable to run contour lines up the stream to the end of the back flow. Four levels, taken at different places along the creek, gave an average fall of 10.2 feet per mile, with a maximum fall of 12.6 feet.

A reservoir at this site would not be of sufficient value to justify the expense of further surveys.

About 2 miles below Logan the land along Canadian River becomes too much broken for irrigation, and this condition continues to the Texas line, about 20 miles farther down. At the time of the reconnaissance not more than 1 second-foot of water was flowing in Ute Creek, although the Canadian River was too high to ford or to gage. However, the drifts along the creek indicate that at times there are floods of considerable magnitude, though their frequency and duration could not be learned with any degree of certainty.

A gage was placed at the Martinez ranch, about 1 mile below the dam site and 7 miles from Logan, and an assistant employed to take readings and make reports. The stream was cross sectioned at the gage and the slope measured.

As Ute Creek has an extensive watershed, a gaging station will be continued on this stream, and the place selected is perhaps as good as any that can be found.

There is a large tract of irrigable land lying north of Logan that would be valuable if water could be put on it. If a reservoir site could be found up Canadian River near the third guide meridian, a canal might be brought down the Canadian and over to Ute Creek in the vicinity of Gallajos, and the water flumed over the latter stream or stored in a reservoir. A thorough survey and examination will be made for such a site.

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[a] From report by W. G. Russell.

PLANS FOR IRRIGATION OF THE RIO GRANDE VALLEY.[a]

GENERAL STATEMENT.

The Rio Grande rises in Colorado and flows south through the entire length of New Mexico to the north boundary of Texas, near Anthony. From this point to "The Pass," about 4 miles above El Paso, Tex., it forms the boundary between New Mexico and Texas. At "The Pass" it becomes the boundary line between the United States and Mexico, and continues as such for about 1,300 miles to the Gulf of Mexico.

So far as its history is known it has always been a torrential or storm-water stream, subject at times to great floods and at other times to periods of minimum flow, when its bed was dry or carried an insignificant amount of water along certain parts of its course.

Above El Paso it has a length of about 900 miles and a drainage area of about 38,000 square miles. In this section its ordinary flow, or what is known as its permanent water, comes almost entirely from a comparatively small area in Colorado and upper New Mexico, where there is a heavy snowfall in the mountains.

The country through which it flows is very fertile, but the rainfall is so meager and so erratic that it is an arid desert and no crops can be raised without artificial irrigation.

Before the middle of the sixteenth century the Spaniards entered the valley of the Rio Grande in New Mexico and there found the Pueblo Indians living in towns, cultivating the land and bringing water onto it by irrigating ditches, many of which are still in use at the present time.

A Spanish colony was established at Chamita, N. Mex., in 1598, and at Santa Fe in 1605. The latter colony existed until 1680, when it was driven out by the Pueblo Indians. Spanish supremacy was again established in 1692. From that time to near the middle of the nineteenth century the Rio Grande Valley in New Mexico was under the dominion of Spain and Mexico and was settled by Spaniards and Mexicans, who irrigated and cultivated the lands. In the excellent report made by Mr. W. W. Follett in 1896 to the International Boundary Commission he says:

> While quite a large native population has come into the Rio Grande drainage in New Mexico since the construction of railroads in 1880, it is confined principally to the towns, and to-day fully 90 per cent of the irrigating in this section is done by Mexicans and Indians.

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[a] From report by B. M. Hall, supervising engineer.

In the same report Mr. Follett says:

> The El Paso Valley was occupied by Spaniards over three hundred years ago. In the year 1600 El Paso del Norte (now called Juarez) was an important town, and records are in existence over two hundred and eighty years old which refer to the Acequia Madre of El Paso del Norte as being in use.

In speaking of his investigations in El Paso Valley Mr. Follett says:

> From all I could learn, I should judge that in former years some 40,000 acres of land were tilled in this valley, more than half of which was on the Mexican side of the river.

During recent years there has been a great scarcity of water in the Rio Grande in New Mexico and in the El Paso Valley of Texas and Mexico. The deficiency of flow at El Paso brought about a complaint from the Republic of Mexico. The question was referred, by a protocol, dated May 6, 1896, to the International Boundary Commission for a full investigation and a report upon the following points:

1. The amount of water of the Rio Grande taken by irrigation canals in the United States of America.
2. The average amount of water in said river, year by year, before the construction of said irrigation canals and since said construction.
3. The best and most feasible mode of so regulating the use of the waters of said river as to secure to each country concerned and to its inhabitants their legal and equitable rights and interests in said waters.

On November 25, 1896, the Commission, composed of Col. Anson Mills for the United States and Señor Don F. Javier Osorno for the Republic of Mexico, having before them the full and complete report of Mr. W. W. Follett, United States engineer for the Commission, reported as follows:

> 1. The increase in the acreage irrigated from the Rio Grande in the State of Colorado from the year 1880 to the year 1896 was 197,000 acres. The increase of acreage irrigated in New Mexico during the same years was 3,000 acres, making a total of 200,000 acres.
>
> 2. The flow of the river at El Paso has been decreased about 200,000 acre-feet of water per annum by the taking of water for irrigation by canals constructed in the United States of America, the great mass of these waters consisting of flood waters utterly unavailable for irrigation without large reservoirs.
>
> 3. As "the best and most feasible mode of regulating the use of water and securing to each country and its inhabitants their legal and equitable rights in said waters," the Commission recommended that the United States Government should buy all necessary land, pay all damages, and construct at its own expense an international dam at "The Pass," about 4 miles above El Paso; submerge 25,565 acres of good land in the United States with water; extend the Mexican boundary upstream to the dam site, giving Mexico 98 acres additional territory in order that one end of the dam may be on Mexican soil;

deed one-half of the dam, the reservoir, and the water supply to the Republic of Mexico, and in some way prevent the construction of any large reservoirs on the Rio Grande in the Territory of New Mexico.

The Commission estimated the cost of this project at $2,317,113.36. As above mentioned, Mr. Follett estimates that about 40,000 acres of land had prior rights under the old canals in El Paso Valley, and were deprived of irrigation by the acts of American citizens on the headwaters; and that something more than one-half of this 40,000 acres lay on the Mexican side of the river. As the restoring of these ancient water rights is the primary object of the proposed expenditure of $2,317,113.36, the cost of the project would be $57.92 per acre. However, it will be shown further along in this paper that the proposed reservoir could be made to irrigate 55,000 acres in El Paso Valley, which would put the cost per acre at $42.12, provided the estimate of the Commission is a correct one. There is every reason for believing this estimate too low; but aside from the monetary cost per acre for the land to be irrigated there is another item of cost to be considered. The reservoir would cover 25,565 acres of good valley land with mud and water and would cause marshes to form in the low, flat valley at the head of the lake, amounting to perhaps 15,000 acres additional, making a total destruction of about 40,000 acres of land in Mesilla Valley, which is just as near to El Paso and just as valuable as any of the land that would be irrigated.

While the published report of the Commission and its engineers plainly sets forth the fact that increased irrigation in Colorado caused shortage of water in Mexico, Texas, and New Mexico, the recommendations not only leave New Mexico out of all the benefits to be derived from a project inaugurated for the purpose of making up this shortage, but give part of her territory to Mexico; cover up another part of it by the proposed reservoir, and distinctly ask that the Government shall prevent the construction of any other large reservoir on the Rio Grande in the Territory of New Mexico. The only reasonable explanation of these recommendations lies in the probable fact that the Commission had no alternative plan for consideration, and thought that the plan recommended was the only possible means that could be adopted for restoring the water to which Mexico laid claim by virtue of ancient prior use. Indeed they were confronted at the time with the prospect of an Elephant Butte dam in New Mexico, not under Government management, but to be constructed, owned, and operated by a stock company of private capitalists, whose plans contemplated the construction of a comparatively low dam without sufficient storage capacity for irrigating a large area above and leaving a surplus for Mexico. Now that conditions have completely changed, and there is an alternative plan which it is claimed will accomplish just as much for Mexico and a great deal more for the United States, it becomes necessary to compare these two plans and choose between them.

The alternative plan suggested by the Reclamation Service is to build a storage dam opposite Engle, N. Mex., across the Rio Grande at a point about one-third mile below the site selected by the old Elephant Butte Company and one-half mile below Elephant Butte, which is a conical mountain peak rising abruptly from the river bank to a height of about 500 feet. At this site it is proposed to build a dam that will form a reservoir 175 feet deep at its lower end and 40 miles long, with a storage capacity of 2,000,000 acre-feet, enough water to furnish 600,000 acre-feet per annum and irrigate 180,000 acres of land, distributed as follows:

Land irrigable from Engle reservoir, New Mexico.

	Acres.
New Mexico	110,000
Texas above El Paso	20,000
El Paso Valley below El Paso, in Texas and Mexico	50,000

In considering these projects or any other plans of water storage on the Rio Grande it is well to keep in mind the following facts:

(1) While the floods on the river are enormous, they do not come with any regularity, and the total flow in some years is less than one-tenth of the total flow in other years.

(2) Any reservoir constructed on the river will stop all the silt that comes down the river in suspension. Hence a small reservoir will accumulate as many acre-feet of mud per year as a large one until it is filled with mud.

(3) All the water that comes down the river is needed for irrigation, and none should be wasted.

These three conditions make it imperative that the reservoir should be as large and as deep as possible, and should have capacity for carrying a supply of water over from year to year to equalize the yearly inequalities, a surplus capacity for mud accumulations, and a surface for evaporation that is as small as possible in comparison with the quantity of water in storage.

FLOOD STORAGE ON THE RIO GRANDE.

The following is a study of the service that could have been performed by the proposed "international dam" at El Paso, Tex., and by the proposed dam near Engle, N. Mex., from January, 1897, to June, 1904, inclusive, in the storage of the flood waters of the Rio Grande and their distribution for irrigation.

This study necessarily requires a knowledge of the following conditions:

(1) The quantity of water flowing in the river during each month of the period specified.

(2) The percentage of mud, or silt, carried in suspension by the water to be deposited in the reservoir.

(3) The depth of evaporation from the surface of the reservoir for each month in the year.

(4) The storage capacity and area of water surface of the reservoir at different levels from bottom to top.

From these a fair estimate may be made of the amount of water available for irrigation, the quantity of mud that will accumulate in the reservoir, and the total number of years that the reservoir can be used for the service required without cleaning out the accumulated mud. It has been assumed that either reservoir will give good service until the mud in it fills 60 per cent of its capacity.

PERCENTAGE OF SILT IN WATER.

The following silt measurements of Rio Grande water at El Paso, Tex., are from samples taken under the supervision of the United States consulting engineer of the International Boundary Commission, the percentage of silt being determined by Prof. J. C. Nagle, of the Agricultural and Mechanical College of Texas. The percentage of silt by volume for seven days' settlement was obtained by filling a tube with 100 cubic centimeters of muddy water, allowing it to stand for a week, and reading the height of mud in the bottom of the tube. The percentage by weight was obtained by drying and weighing the mud deposit and comparing its weight with that of the 100 cubic centimeters of water.

The measurements made in September, 1900, are published on page 382, Bulletin No. 119, Office of Experiment Stations, United States Department of Agriculture. Those for 1901 and 1902 are published on page 206, Bulletin No. 113, of same Department. Those for 1897, 1898, and 1903, and for June, 1900, were obtained from a letter from Prof. J. C. Nagle to Mr. W. W. Follett. The whole data is given here, but only the percentage by weight will be used, and this will be converted into percentage by volume by a method hereinafter described.

Percentage of silt in the waters of the Rio Grande at El Paso, Tex.

Date.	Per cent of silt, by volume, after standing 7 days.	Per cent of silt, by weight, dry.	Discharge of river in second-feet when sample was taken.
May 7, 1897	3.39	....	5,980
May 11, 1897	5.04	....	7,240
September 23, 1897	15.94	....	550
May 21, 1898	2.76	....	1,700
November 8, 1898	1.52	....	....
June 27, 1900	.74	....	95
June 29, 1900	.64	....	45
September 9, 1900	8.49	3.91	830
Do	22.20	5.52	830

Percentage of silt in the waters of the Rio Grande at El Paso, Tex.—Continued.

Date.	Per cent of silt, by volume, after standing 7 days.	Per cent of silt, by weight, dry.	Discharge of river in second-feet when sample was taken.
September 13, 1900	15.74	3.70	1,690
Do	17.67	4.29	1,690
September 15, 1900	18.40	5.15	740
September 18, 1900	17.74	4.90	680
September 20, 1900	33.22	8.66	160
September 24, 1900	12.81	3.37	45
February 14, 1901	6.05	1.36	90
February 15, 1901	5.86	1.47	110
February 16, 1901	6.02	1.47	180
May 2, 1901	12.42	3.98	1,020
May 4, 1901	10.29	2.96	1,520
May 5, 1901	6.07	1.92	1,880
May 6, 1901	6.01	2.03	2,380
May 7, 1901	5.83	1.95	3,050
May 8, 1901	5.84	1.99	3,100
May 9, 1901	5.86	1.64	2,340
April 26, 1902	8.22	1.56	465
April 28, 1902	13.55	3.61	425
April 30, 1902	5.45	1.35	145
May 2, 1902	6.81	2.06	60
May 7, 1902	.40	.06	5
June 3, 1902	8.23	2.46	135
February 27, 1903	8.88	1.69	25
March 11, 1903	16.51	4.04	1,360
March 24, 1903	2.91	1.82	405
April 10, 1903	8.04	2.69	1,020
April 24, 1903	1.53	1.41	660
May 9, 1903	4.35	1.80	2,452
May 16, 1903	2.45	.64	5,060
May 25, 1903	1.12	.52	4,430
May 31, 1903	2.20	.64	2,340
June 6, 1903	1.29	.40	2,590
June 18, 1903	4.66	.89	16,000
June 26, 1903	1.58	.53	16,660
June 29, 1903	.76	.22	12,430
July 2, 1903	1.06	.15	10,030
July 7, 1903	.94	.28	3,540
July 12, 1903	1.27	.17	1,740
July 16, 1903	.98	.15	970
July 24, 1903	1.39	.70	1,000

On June 29, 1904, Messrs. Follett and Hall cut a 3-inch cube of wet silt mud from the bed of the Rio Grande and had it dried at a low temperature and weighed by Mr. Arthur W. Houck, assayer. It weighed 5,789 grains, and shows that a cubic foot of silt mud dried out will weigh 53 pounds, which is 85 per cent of the weight of a cubic foot of water.

In the following table column A shows the percentage of silt in Rio Grande water by weight in different months and years, as estimated and tabulated by Mr. Follett from the foregoing silt measurements and from his observed changes in turbidity for different seasons and stages of the river. Column B shows the percentage of silt mud in a compacted state by volume, based on the dry weight of a cubic foot of such mud, found, as above described, to be 85 per cent of the weight of a cubic foot of water. The figures of column B are, therefore, obtained by dividing the figures of column A by 0.85, and are the figures used for estimating the mud accumulations by volume from month to month.

Percentage of silt, by weight, "A," and by compacted volume, "B," in the waters of the Rio Grande from January, 1897, to June, 1904, inclusive.

[By W. W. Follett and B. M. Hall.]

Month.	1897.		1898.		1899.		1900.	
	A.	B.	A.	B.	A.	B.	A.	B.
January	2.40	2.82	0.90	1.06	0.90	1.06	0.90	1.06
February	2.40	2.82	.90	1.06	.90	1.06	.90	1.06
March	2.40	2.82	.90	1.06	1.40	1.65	.50	.59
April	2.06	2.42	2.38	2.80	2.00	2.35	.30	.35
May	.81	.95	1.00	1.18	1.40	1.65	1.62	1.91
June	.52	.61	1.00	1.18	....	....	1.00	1.18
July	.52	.61	1.00	1.18	4.90	5.76	.30	.35
August	4.00	4.71	1.00	1.18	.50	.59	....	....
September	5.45	6.41	1.00	1.18	....	....	4.94	5.81
October	3.75	4.41	....	....	....	....	....	....
November	2.06	2.42	....	....	....	....	....	....
December	.90	1.06	1.00	1.18	.90	1.06	1.00	1.18

Percentage of silt, by weight, "A," and by compacted volume, "B," in the waters of the Rio Grande from January, 1897, to June, 1904, inclusive—Continued.

Month.	1901.		1902.		1903.		1904.	
	A.	B.	A.	B.	A.	B.	A.	B.
January	1.00	1.18	0.50	0.59	1.70	2.00	1.00	1.18
February	1.43	1.68	.50	.59	1.69	1.99	.50	.59
March	1.40	1.65	.30	.35	2.38	2.80	....	....
April	....	....	2.17	2.55	2.06	2.42	....	....
May	1.62	1.91	2.06	2.42	.90	1.06	....	....
June	1.00	1.18	2.46	2.89	.52	.61	....	....
July	4.94	5.81	....	....	.29	.34	....	....
August	4.94	5.81	4.94	5.81	1.40	1.65	....	....
September	4.94	5.81	4.94	5.81	1.40	1.65	....	....
October	4.94	5.81	.50	.59	1.40	1.65	....	....
November	1.43	1.68	.50	.59	.50	.59	....	....
December	.50	.59	.50	.59	1.00	1.18	....	....

EVAPORATION FROM SURFACE OF RESERVOIR.

The figures given below, showing evaporation at Fort Bliss, near El Paso, Tex., in 1889 and 1890, were published in Twelfth Annual Report United States Geological Survey, part 2, page 235, and in Thirteenth Annual Report, part 3, page 411.

Estimated evaporation from surface of proposed reservoir at El Paso.

Month	In inches.	Decimals of a foot.
January	2.0	0.17
February	2.0	.17
March	7.0	.58
April	7.3	.61
May	10.8	.90
June	11.2	.94
July	9.6	.80
August	11.4	.95
September	9.2	.77
October	6.8	.56
November	4.6	.38
December	2.9	.24
Annual	84.8	7.07

In the following discussion it is assumed that the tables on pages 401–402 are applicable alike to the El Paso reservoir and to the Elephant Butte reservoir, and they will be used in both cases for finding the volume of mud deposited and the loss of water by evaporation. The other data entering into these calculations will be the " inflow of water for each month " and the capacity and surface area of the reservoir at all levels of water. It is evident that these items will be different for different reservoirs and localities, and therefore they will be considered separately for each reservoir.

PROPOSED INTERNATIONAL RESERVOIR AT EL PASO.

The proposed El Paso dam would be constructed at " The Pass," 4 miles above El Paso, and would be of a height sufficient to give a depth of 63.5 feet of water just above the dam. When full, the area of water surface would be 25,565 acres. With the water standing 43.5 feet deep just above the dam its surface would cover only 12,428 acres, and its contents would be only one-third of the capacity of the full reservoir. Thirteen thousand acres of land covered by the full reservoir would be submerged to a depth of less than 20 feet. The following table of capacities and areas is made by Mr. W. W. Follett from his own surveys and contour maps of the basin:

Capacities and surface areas of proposed El Paso reservoir at different elevations.

[By W. W. Follett.]

Elevation above sea level (Southern Pacific Rwy. datum).	Depth of water in feet.	Area of water surface in acres.	Capacity in acre-feet.	Elevation above sea level (Southern Pacific Rwy. datum).	Depth of water in feet.	Area of water surface in acres.	Capacity in acre-feet.
Feet.				*Feet.*			
3,710	0	0	0	3,728	18	2,378	16,180
3,715	5	180	0	3,729	19	2,551	18,645
3,716	6	333	256	3,730	20	2,725	21,283
3,717	7	486	666	3,731	21	2,968	24,129
3,718	8	639	1,228	3,732	22	3,211	27,219
3,719	9	792	1,944	3,733	23	3,455	30,552
3,720	10	946	2,813	3,734	24	3,699	34,129
3,721	11	1,128	3,850	3,735	25	3,943	37,950
3,722	12	1,311	5,069	3,736	26	4,264	42,053
3,723	13	1,494	6,472	3,737	27	4,585	46,478
3,724	14	1,677	8,057	3,738	28	4,906	51,223
3,725	15	1,859	9,825	3,739	29	5,227	56,290
3,726	16	2,032	11,770	3,740	30	5,548	61,677
3,727	17	2,205	13,889	3,741	31	6,099	67,501

Capacities and surface areas of proposed El Paso reservoir at different elevations—Cont'd.

[By W. W. Follett.]

Elevation above sea level (Southern Pacific Rwy. datum).	Depth of water in feet.	Area of water surface in acres.	Capacity in acre-feet.	Elevation above sea level (Southern Pacific Rwy. datum).	Depth of water in feet.	Area of water surface in acres.	Capacity in acre-feet.
Feet.				*Feet.*			
3,742	32	6,650	73,876	3,759	49	14,639	259,279
3,743	33	7,201	80,801	3,760	50	15,013	274,105
3,744	34	7,752	88,278	3,761	51	15,675	289,449
3,745	35	8,304	96,306	3,762	52	16,337	305,455
3,746	36	8,794	104,855	3,763	53	16,999	322,123
3,747	37	9,285	113,894	3,764	54	17,661	339,453
3,748	38	9,776	123,425	3,765	55	18,324	357,445
3,749	39	10,267	133,446	3,766	56	19,125	376,170
3,750	40	10,758	143,959	3,767	57	19,926	395,695
3,751	41	11,235	154,955	3,768	58	20,727	416,022
3,752	42	11,712	166,429	3,769	59	21,528	437,149
3,753	43	12,189	178,379	3,770	60	22,328	459,077
3,754	44	12,667	190,807	3,771	61	23,253	481,868
3,755	45	13,145	203,713	3,772	62	24,178	505,583
3,756	46	13,518	217,044	3,773	63	25,103	530,224
3,757	47	13,891	230,749	3,773½	63½	25,565	542,891
3,758	48	14,265	244,827				

Monthly discharge, in acre-feet, of the Rio Grande at El Paso, Tex.

Month.	1897.[a]	1898.	1899.	1900.	1901.	1902.	1903.	1904.
January	3,100	30,129	12,912	8,110	278	8,291	615	972
February	10,080	33,655	11,330	5,680	4,503	5,772	1,289	387
March	9,920	20,044	7,071	460	3,669	635	22,602	0
April	128,400	97,944	8,807	300	0	7,904	49,468	0
May	511,101	140,192	10,330	44,810	158,102	526	203,623	0
June	362,697	111,570	0	93,100	77,038	307	586,909	0
July	81,739	196,269	19,553	70	12,576	20	158,202	....
August	8,132	31,236	430	0	60,655	14,499	4,334	....
September	41,950	2,262	0	16,483	21,005	9,313	1,031	....
October	108,099	160	123	0	5,336	1,428	2,033	....
November	69,322	119	119	0	12,813	298	298	....
December	40,205	5,718	2,828	738	7,993	1,775	2,440	....
The year	1,374,745	669,298	73,503	169,751	363,968	50,768	1,032,844	....

[a] Previous estimates revised.

WATER USED FOR IRRIGATION.

It has been found that 180,000 acre-feet per year will be the largest amount of irrigation water that can be realized from this reservoir at El Paso. A proper distribution of this amount of water for this region will be as follows:

Water used for irrigation in each month.

	Acre-feet.
January	0
February	3,600
March	16,200
April	36,000
May	36,000
June	36,000
July	25,200
August	12,600
September	9,000
October	3,600
November	1,800
December	0
The year	180,000

SERVICE OF RESERVOIR.

Proper conclusions can now be formed as to the service that can be performed by the proposed reservoir, and estimates made of the length of time required for it to fill with mud to the point where its capacity will be less than that necessary for storage unless some means of cleaning out this mud is resorted to or the mud is prevented from entering the reservoir by means of settling basins above. Such expedients will be considered later in this paper, but for the purposes of discussion and comparison of the two reservoirs it will be assumed that the mud which settles in the reservoir remains there, at least until the reservoir becomes inefficient by reason of its accumulation.

The method of calculation used in computing the service tables is as follows:

(1) The "inflow" is taken from table on page 404.

(2) The "silt deposited in month" is found by multiplying the "inflow" by the percentage in column B of the table on pages 401–402.

(3) "Water available" equals the "inflow" minus the "silt deposited" plus the "water in reservoir" at end of preceding month.

(4) "Silt in reservoir" is the total accumulation at end of each month.

(5) "Loss by evaporation" is figured by first adding together the "water available" and "silt in reservoir" to get the total contents of reservoir; then, by finding this amount in the last column of table on

pages 403–404, taking the corresponding water surface in acres from the same table, and multiplying by the evaporation in "decimals of a foot" in the last column of the table on page 402 for the given month. (See (1) below.)

(6) "Water used for irrigation" is from table on page 405.

(7) "Water in reservoir at end of month" equals "water available" minus "loss by evaporation" minus "use for irrigation" in month.

(8) "Deficiency" is the deficiency in amount necessary for irrigation.

(9) To find the "overflow," subtract "silt in reservoir" from total capacity of reservoir. This gives the water capacity of the reservoir at end of given month. If the water left over after subtracting "evaporation" and "irrigation" from "water available" exceeds this amount, the excess is the "overflow."

It is to be noted: (1) That the "loss by evaporation" can not exceed the "water available." (See October and November, 1902.) It is also limited by the surface area of the reservoir during months in which there is an overflow.

(2) That the water "used for irrigation" is limited by the quantity available. This quantity subtracted from the water required for irrigation gives the "deficiency." (See October and November, 1902, and February, 1903.)

(3) That the water capacity of the reservoir limits the amount of "water in reservoir at end of month." (See months having an "overflow.")

Estimated data concerning the proposed international reservoir on the Rio Grande at El Paso, from January, 1897, to June, 1904, inclusive.[a]

Date.	Inflow.	Silt deposited in month.	Water available.	Silt in reservoir.	Lost by evaporation.	Used for irrigation.	Water in reservoir at end of month.	Deficiency.	Overflow.
1897.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-ft.*	*Acre-ft.*
January	3,100	87	3,013	87	110	0	2,903	0	0
February	10,080	284	12,699	371	357	3,600	8,742	0	0
March	9,920	280	18,382	651	1,856	16,200	326	0	0
April	128,400	3,107	125,619	3,758	6,100	36,000	83,519	0	0
May	511,101	4,855	589,765	8,613	23,400	36,000	530,365	0	0
June	362,697	2,212	890,850	10,825	24,440	36,000	532,066	0	298,344
July	81,739	500	613,305	11,325	20,800	25,200	531,566	0	35,739
August	8,132	383	539,315	11,708	24,700	12,600	502,015	0	0
September	41,950	2,689	541,276	14,397	20,020	9,000	512,256	0	0
October	108,099	4,767	615,588	19,164	14,560	3,600	523,727	0	73,701
November	69,322	1,678	591,371	20,842	9,880	1,800	522,049	0	57,642
December	40,205	426	561,828	21,268	6,240	0	521,623	0	33,965
Total for year	1,374,745	21,268	....	....	152,463	180,000	....	....	499,391

[a] This table contains slight inaccuracies, but they do not affect results.

Estimated data concerning the proposed international reservoir on the Rio Grande at El Paso, from January, 1897, to June, 1904, inclusive—Continued.

Date.	Inflow.	Silt deposited in month.	Water available.	Silt in reservoir.	Lost by evaporation.	Used for irrigation.	Water in reservoir at end of month.	Deficiency.	Overflow.
1898.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-ft.*	*Acre-ft.*
January	30,129	319	551,433	21,587	4,420	0	521,304	0	25,709
February	33,655	357	554,602	21,944	4,420	3,600	520,947	0	25,635
March	20,044	212	540,779	22,156	15,080	16,200	509,499	0	0
April	97,944	274	607,169	22,430	15,860	36,000	520,461	0	34,848
May	140,192	1,654	658,999	24,084	23,400	36,000	518,807	0	80,792
June	111,570	1,317	629,060	25,401	24,440	36,000	517,490	0	51,130
July	196,269	2,316	711,443	27,717	20,800	25,200	515,174	0	150,269
August	31,236	369	546,041	28,086	24,700	12,600	508,741	0	0
September	2,262	27	510,976	28,113	19,558	9,000	482,418	0	0
October	160	0	482,578	28,113	13,664	3,600	465,314	0	0
November	119	0	465,433	28,113	9,206	1,800	454,427	0	0
December	5,718	67	460,078	28,180	5,640	0	454,438	0	0
Total for year	669,298	6,912	....	....	181,188	180,000	....	....	368,383
1899.									
January	12,912	137	467,213	28,317	4,046	0	463,167	0	0
February	11,330	120	474,377	28,437	4,097	3,600	466,680	0	0
March	7,071	117	473,634	28,554	13,920	16,200	443,514	0	0
April	8,807	207	452,114	28,761	14,152	36,000	401,962	0	0
May	10,330	170	412,122	28,931	19,530	36,000	355,592	0	0
June	0	0	356,592	28,931	18,330	36,000	302,262	0	0
July	19,553	1,126	320,689	30,057	14,400	25,200	281,089	0	0
August	430	3	281,516	30,060	15,675	12,600	253,241	0	0
September	0	0	253,241	30,060	11,858	9,000	232,383	0	0
October	123	0	232,506	30,060	8,232	3,600	220,674	0	0
November	119	0	220,793	30,060	5,472	1,800	213,521	0	0
December	2,828	30	216,319	30,090	3,432	0	212,887	0	0
Total for year	73,503	1,910	....	....	133,144	180,000	....	0	
1900.									
January	8,110	86	220,911	30,176	2,465	0	218,446	0	
February	5,680	60	224,066	30,236	2,473	3,600	217,993	0	
March	460	3	218,450	30,239	8,323	16,200	193,927	0	
April	300	1	194,226	30,240	8,357	36,000	149,869	0	
May	44,810	856	193,823	31,096	12,330	36,000	145.493	0	0
June	93,100	1,099	237,494	32,195	14,006	36,000	187,488	0	0
July	70	0	187,558	32,195	10,880	25,200	151,178	0	0
August	0	0	151,478	32,195	11,685	12,600	127,193	0	0
September	16,483	958	142,718	33,153	9,240	9,000	124,478	0	0
October	0	0	124,478	33,153	6,356	3,600	114,522	0	0
November	0	0	114,522	33,153	4,142	1,800	108,580	0	0
December	738	9	109,309	33,162	2,568	0	106,741	0	0
Total for year	169,751	3,072	....	....	92.825	180,000	....	0	0
1901.									
January	278	3	107,016	33,165	1,802	0	105,214	0	0
February	4,503	76	109,641	33,241	1,819	3,600	104,222	0	0
March	3,669	60	107,831	33,301	6,177	16,200	85,454	0	0
April	0	0	85,454	33,301	5,795	36,000	43,659	0	0

Estimated data concerning the proposed international reservoir on the Rio Grande at El Paso, from January, 1897, to June, 1904, inclusive—Continued.

Date.	Inflow.	Silt deposited in month.	Water available.	Silt in reservoir.	Lost by evaporation.	Used for irrigation.	Water in reservoir at end of month.	Deficiency.	Overflow.
1901.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-ft.*	*Acre-ft.*
May	158,102	3,020	198,741	36,321	12,600	36,000	150,141	0	0
June	77,038	909	226,270	37,230	13,818	36,000	176,452	0	0
July	12,576	731	188,297	37,961	10,960	25,200	152,137	0	0
August	60,655	3,524	209,268	41,485	13,680	12,600	182,988	0	0
September	21,005	1,220	202,773	42,705	11,011	9,000	182,762	0	0
October	5,336	310	187,788	43,015	7,784	3,600	176,404	0	0
November	12,813	215	189,002	43,230	5,301	1,800	181,901	0	0
December	7,993	47	189,847	43,277	3,348	0	186,499	0	0
Total for year	363,968	10,115	....	....	94,095	180,000	....	0	0
1902.									
January	8,291	49	194,741	43,326	2,397	0	192,344	0	0
February	5,772	34	198,082	43,360	2,414	3,600	192,068	0	0
March	635	2	192,701	43,362	8,149	16,200	168,352	0	0
April	7,904	202	176,054	43,564	8,296	36,000	131,758	0	0
May	526	13	132,271	43,577	10,890	36,000	85,381	0	0
June	307	9	85,679	43,586	9,400	36,000	40,279	0	0
July	20	0	40,299	43,586	5,920	25,200	9,179	0	0
August	14,499	842	22,836	44,428	5,785	12,600	4,451	0	0
September	9,313	541	13,223	44,969	1,158	9,000	65	0	0
October	1,428	8	1,485	44,977	0	1,485	0	[a] 2,115	0
November	298	2	296	44,979	0	296	0	[a] 1,504	0
December	1,775	10	1,765	44,989	1,104	0	661	0	0
Total for year	50,768	1,712	....	....	58,513	176,381	....	3,619	0
1903.									
January	615	12	1,264	45,001	777	0	487	0	0
February	1,289	26	1,750	45,027	0	1,750	0	[a] 1,850	0
March	22,602	633	21,969	45,660	3,550	16,200	2,219	0	0
April	49,468	1,197	50,490	46,857	5,100	36,000	9,390	0	0
May	203,623	2,158	210,855	49,015	13,185	36,000	161,670	0	0
June	586,909	3,580	744,999	52,595	24,110	36,000	490,296	0	194,263
July	158,202	538	647,960	53,133	20,800	25,200	489,758	0	112,202
August	4,334	72	494,020	53,205	24,700	12,600	456,720	0	0
September	1,031	17	457,734	53,222	18,788	9,000	429,946	0	0
October	2,033	34	431,945	53,256	13,104	3,600	415,241	0	0
November	298	2	415,537	53,258	8,722	1,800	405,015	0	0
December	2,440	29	407,426	53,287	5,369	0	402,057	0	0
Total for year	1,032,844	8,298	....	....	138,535	178,150	....	1,850	306,465
1904.									
January	972	11	403,018	53,298	3,774	0	399,244	0	0
February	387	2	399,629	53,300	3,740	3,600	392,289	0	0
March	0	0	392,289	53,300	12,644	16,200	363,445	0	0
April	0	0	363,445	53,300	12,657	36,000	314,788	0	0
May	0	0	314,788	53,300	16,920	36,000	261,868	0	0
June	0	0	261,868	53,300	15,698	36,000	210,170	0	0

[a] Deficiency equals amount required for irrigation less amount used for irrigation.

Summary of data concerning the proposed international reservoir on Rio Grande at El Paso, from January, 1897, to June, 1904.

Year.	Inflow from river.	Silt deposited.	Lost by evaporation.	Used for irrigation.	Lost by overflow.	Water in reservoir at end of year.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1897	1,374,745	21,268	152,463	180,000	499,391	521,623
1898	669,298	6,912	181,188	180,000	368,383	454,438
1899	73,503	1,910	133,144	180,000	....	212,887
1900	169,751	3,073	93,825	180,000	....	106,741
1901	363,968	10,115	94,095	180,000	....	186,499
1902 [a]	50,768	1,712	58,513	176,381	....	661
1903 [b]	1,032,844	8,298	138,585	178,150	306,465	402,057
1904 (half year)	1,359	13	65,433	127,800	....	210,170
Total for 7½ years	3,736,236	53,300	917,196	1,382,331	1,174,239	....
Average per year	498,165	7,107	122,293	180,000	156,565	....
Percentage of inflow		1.43	24.55	37.00	32.00	5.02

[a] Empty in October and November.

[b] Empty in February.

The above table for proposed El Paso reservoir shows:

(1) That the accumulated mud in the reservoir at the end of seven and a half years would be 53,300 acre-feet, deposited at the rate of 7,107 acre-feet per year. At the end of forty-six years this would amount to 325,735 acre-feet, or 60 per cent of the entire capacity of the reservoir, leaving only 217,000 acre-feet of water capacity in the reservoir, unless some means of getting rid of this mud is devised. The mud in the reservoir would have a maximum depth of 46 feet, and its surface would cover an area of valley land about 3 miles wide and 13½ miles long. The entire water space above this mud would have a maximum depth of 17½ feet, covering an area of 25,000 acres.

(2) The tabulated statement shows that a very large amount of water is wasted through the overflow, because the dam can not be made high enough to hold it. Even if the material of the hills on either side were of such a nature that a safe dam could be built, with a spillway 63.5 feet above the river bed, the height of these hills is such that the spillway could not reasonably be at a greater elevation.

(3) A supply of 180,000 acre-feet per year is estimated for irrigation, but although it is shown that only 176,381 acre-feet will be available in 1902 and 178,150 acre-feet in 1903, the waste by overflow amounts to 36 per cent of the inflow in 1897, 55 per cent of the inflow in 1899, and nearly 30 per cent of the inflow in 1903.

During the seven and a half years the water that flows into the reservoir is disposed of as follows:

Disposition of water at proposed international reservoir on Rio Grande at El Paso.

	Per cent.
Loss by sediment	1.43
Loss by evaporation	24.55
Loss by overflow	32.00
Total loss	57.98
Water used for irrigation	37.00
Water in reservoir at end of 7½ years	5.02
Total	100.00

PROPOSED RESERVOIR NEAR ENGLE, N. MEX.

The Engle dam would be constructed in a narrow gorge of the river below the site that was proposed for the dam of the old Elephant Butte Company. According to surveys of the Reclamation Service, the proposed reservoir would have a depth of 160 feet just above the dam, and a storage capacity of 1,500,000 acre-feet. Recent additional surveys made by J. L. Rhead, under the direction of B. M. Hall, show that it will be practicable to build a dam at this point 230 feet above the river bed, but there is a natural gap in the hill to the west, several miles above the dam, that has an elevation of only 4,383 feet above sea level. A spillway can be made at this point at an elevation of 4,385 feet, limiting the water depth to 175 feet. If the water is 175 feet deep, the reservoir would have a capacity of 2,000,000 acre-feet, as shown in the following table, which is based on topographic surveys of the Reclamation Service up to an elevation of 4,370 feet. Areas and capacities from 160 to 175 feet of depth are calculated by percentage of increase. This reservoir will be deep and narrow, and sediment could be cleaned out of it more easily than if it were wide and shallow. The methods of calculation for service in this reservoir are the same as those for the El Paso reservoir.

Area of surface and capacity of Engle reservoir.

Elevation in feet above sea level (Santa Fe Rwy. datum).	Depth of water in feet.	Surface of water in acres.	Capacity to contour in acre-feet.
4,210	0	0.0	0
4,215	5	41.5	110
4,220	10	130.5	415
4,225	15	219.5	1,290
4,230	20	365.0	2,610
4,235	25	511.0	4,825
4,240	30	843.0	7,720
4,245	35	1,175.0	12,765
4,250	40	1,781.0	19,470
4,255	45	2,388.0	29,890
4,260	50	3,145.0	43,350
4,265	55	3,908.0	58,470
4,270	60	4,664.0	82,375
4,275	65	5,426.0	107,600
4,280	70	6,175.0	136,635
4,285	75	6,924.0	169,385
4,290	80	7,630.0	205,880
4,295	85	8,335.0	245,795
4,300	90	8,977.0	289,235
4,305	95	9,620.0	335,730
4,310	100	10,550.0	385,435
4,315	105	11,480.0	440,510
4,320	110	12,553.0	500,240
4,325	115	13,626.0	565,685
4,330	120	14,811.0	636,500
4,335	125	15,996.0	713,515
4,340	130	17,618.0	796,465
4,345	135	19,241.0	888,615
4,350	140	21,370.0	988,875
4,355	145	23,499.0	1,101,045
4,360	150	25,516.0	1,223,065
4,365	155	27,534.0	1,355,690
4,370	160	29,553.0	1,500,000
4,375	165	30,447.0	[a] 1,650,000
4,380	170	35,600.0	[a] 1,815,000
4,385	175	38,400.0	[a] 2,000,000

[a] Estimated.

Monthly discharge, in acre-feet, of Rio Grande at San Marcial (above Elephant Butte).

Month.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.
January	19,553	57,675	27,854	40,582	20,967	22,731	17,197	16,840
February	24,325	59,425	24,603	35,099	25,468	17,435	21,927	18,902
March	40,767	62,164	27,546	33,203	15,114	7,954	46,790	6,060
April	212,548	271,458	54,089	6,248	23,683	40,106	100,007	0
May	755,196	165,832	35,048	123,590	256,126	26,787	318,367	0
June	366,426	126,268	952	159,888	96,178	6,407	660,476	0
July	65,977	167,062	28,407	0	59,286	0	77,841	....
August	6,149	13,835	6,395	0	65,534	49,210	3,064	....
September	114,188	4,641	2,916	73,190	37,607	18,349	1,438	....
October	281,677	1,230	676	0	17,018	823	545	....
November	175,715	11,722	9,521	2,440	20,053	4,641	5,534	....
December	152,736	23,365	21,828	10,084	19,240	11,286	18,883	....
The year	2,215,257	964,677	239,835	484,324	656,274	200,729	1,272,069	....

Water used for irrigation below Engle.

	Acre-feet.
January	0
February	13,000
March	54,000
April	119,000
May	119,000
June	119,000
July	83,000
August	42,000
September	31,000
October	13,000
November	7,000
December	0
The year	600,000

Estimated data concerning the proposed reservoir on the Rio Grande near Engle, N. Mex.

Year.	Inflow.	Silt deposited in month.	Water available.	Silt in reservoir.	Lost by evaporation.	Used for irrigation.	Water in reservoir at end of month.	Deficiency.	Overflow.
1897.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
January	19,553	551	19,002	551	304	0	18,698	0	0
February	24,325	686	42,337	1,237	537	13,000	28,800	0	0
March	40,767	1,150	68,417	2,387	2,320	54,000	12,097	0	0
April	212,548	5,144	219,501	7,531	4,820	119,000	95,681	0	0
May	755,196	7,174	843,703	14,705	16,650	119,000	708,053	0	0
June	366,426	2,235	1,072,244	16,940	21,800	119,000	931,444	0	0
July	65,977	402	997,017	17,342	17,360	83,000	896,659	0	0
August	6,149	290	902,518	17,632	18,800	42,000	841,718	0	0
September	114,188	7,319	948,587	24,951	15,700	31,000	901,887	0	0
October	281,677	12,422	1,171,142	37,373	14,164	13,000	1,143,978	0	0
November	175,715	4,252	1,315,441	41,625	10,487	7,000	1,297,954	0	0
December	152,736	1,619	1,449,071	43,244	7,080	0	1,441,991	0	0
Total for year	2,215,257	43,244	....	....	130,022	600,000	....	....	....

Estimated data concerning the proposed reservoir on the Rio Grande, near Engle, N. Mex.—Continued.

Year.	Inflows.	Silt deposited in month.	Water available.	Silt in reservoir.	Lost by evaporation.	Used for irrigation.	Water in reservoir at end of month.	Deficiency.	Overflow.
1898.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
January	57,675	611	1,499,055	43,855	5,065	0	1,493,990	0	0
February	59,425	630	1,552,785	44,485	5,100	13,000	1,534,685	0	0
March	62,164	659	1,596,190	45,144	17,285	54,000	1,524,905	0	0
April	271,458	7,601	1,788,762	52,745	21,960	119,000	1,647,802	0	0
May	165,832	1,957	1,811,677	54,702	32,760	119,000	1,659,917	0	0
June	126,268	1,490	1,784,695	56,192	33,840	119,000	1,631,855	0	0
July	167,062	1,971	1,796,946	58,163	28,920	83,000	1,685,026	0	0
August	13,835	163	1,698,698	58,326	31,490	42,000	1,625,208	0	0
September....	4,641	55	1,629,794	58,381	24,100	31,000	1,574,694	0	0
October	1,230	0	1,575,924	58,381	16,970	13,000	1,545,954	0	0
November....	11,722	0	1,557,676	58,381	11,470	7,000	1,539,206	0	0
December	23,365	276	1,562,295	58,657	7,250	0	1,555,045	0	0
Total for year	964,677	15,413	....	....	236,210	600,000	....	0	0
1899.									
January	27,854	295	1,582,604	58,952	5,168	0	1,577,436	0	0
February	24,603	261	1,601,778	59,213	5,233	13,000	1,583,545	0	0
March	27,546	455	1,610,636	59,668	18,021	54,000	1,538,615	0	0
April	54,089	1,271	1,591,433	60,939	18,611	119,000	1,453,822	0	0
May	35,048	578	1,488,292	61,517	26,865	119,000	1,342,427	0	0
June	952	0	1,343,379	61,517	26,517	119,000	1,197,862	0	0
July	28,407	1,636	1,224,633	63,153	21,096	83,000	1,120,537	0	0
August	6,395	38	1,126,894	63,191	23,731	42,000	1,061,163	0	0
September....	2,916	0	1,064,079	63,191	18,428	31,000	1,014,651	0	0
October.......	676	0	1,015,327	63,191	12,914	13,000	989,413	0	0
November....	9,521	0	998,934	63,191	8,645	7,000	983,289	0	0
December	21,828	231	1,004,886	63,422	5,486	0	999,400	0	0
Total for year	239,835	4,765	....	....	190,715	600,000	....	0	0
1900.									
January	40,582	430	1,039,552	63,852	4,002	0	1,035,550	0	0
February	35,099	372	1,070,277	64,224	4,090	13,000	1,053,187	0	0
March	33,203	196	1,086,194	64,420	14,106	54,000	1,018,088	0	0
April	6,248	22	1,024,314	64,442	14,182	119,000	891,132	0	0
May	123,590	2,261	1,012,461	66,703	20,763	119,000	872,698	0	0
June	159,888	1,887	1,030,699	68,590	22,043	119,000	889,656	0	0
July	0	0	889,656	68,590	16,576	83,000	790,080	0	0
August	0	0	790,080	68,590	17,774	42,000	730,306	0	0
September....	73,190	4,252	799,244	72,842	14,707	31,000	753,537	0	0
October	0	0	753,537	72,842	10,158	13,000	730,379	0	0
November....	2,440	0	732,819	72,842	6,768	7,000	719,051	0	0
December	10,084	119	729,016	72,961	4,250	0	724,766	0	0
Total for year	484,324	9,539	....	....	149,419	600,000	....	0	0
1901.									
January	20,967	247	745,486	73,208	3,062	0	742,424	0	0
February	25,468	424	767,468	73,632	3,128	13,000	751,340	0	0
March	15,114	249	766,205	73,881	10,660	54,000	701,545	0	0
April	23,683	0	725,228	73,881	10,773	119,000	595,455	0	0

Estimated data concerning the proposed reservoir on the Rio Grande near Engle, N. Mex.—Continued.

Year.	Inflow.	Silt deposited in month.	Water available.	Silt in reservoir.	Lost by evaporation.	Used for irrigation.	Water in reservoir at end of month.	Deficiency.	Overflow.
1901.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
May	256,126	4,892	846,689	78,773	18,018	119,000	709,671	0	0
June	96,178	1,135	804,714	79,908	18,010	119,000	667,704	0	0
July	59,286	3,445	723,545	83,353	14,240	83,000	626,305	0	0
August	65,534	3,808	688,031	87,161	16,340	42,000	629,691	0	0
September	37,607	2,185	665,113	89,346	12,936	31,000	621,177	0	0
October	17,018	989	637,206	90,335	9,111	13,000	615,095	0	0
November	20,053	337	634,811	90,672	6,167	7,000	621,644	0	0
December	19,240	114	640,770	90,786	3,924	0	636,846	0	0
Total for year	656,274	17,825	....	....	126,369	600,000	....	0	0
1902.									
January	22,731	134	659,443	90,920	2,842	0	656,601	0	0
February	17,435	103	673,933	91,023	2,890	13,000	658,043	0	0
March	7,954	28	665,969	91,051	9,773	54,000	602,196	0	0
April	40,106	1,023	641,279	92,074	9,992	119,000	512,287	0	0
May	26,787	648	538,426	92,722	13,248	119,000	406,178	0	0
June	6,407	185	412,400	92,907	11,882	119,000	281,518	0	0
July	0	0	281,518	92,907	8,280	83,000	190,238	0	0
August	49,210	2,859	236,589	95,766	9,101	42,000	185,488	0	0
September	13,349	776	198,061	96,542	6,968	31,000	160,093	0	0
October	823	5	160,911	96,547	4,766	13,000	143,145	0	0
November	4,641	27	147,759	96,574	3,154	7,000	137,605	0	0
December	11,286	67	148,824	96,641	2,000	0	146,824	0	0
Total for year	200,729	5,855	....	....	84,896	600,000	....	0	0
1903.									
January	17,197	344	163,677	96,985	1,453	0	162,224	0	0
February	21,927	436	183,715	97,421	1,504	13,000	169,211	0	0
March	46,790	1,310	214,691	98,731	5,400	54,000	155,291	0	0
April	100,007	2,420	252,878	101,151	6,076	119,000	127,802	0	0
May	318,367	3,375	442,794	104,526	11,988	119,000	311,806	0	0
June	660,476	4,029	968,253	108,555	21,648	119,000	827,605	0	0
July	77,841	265	905,181	108,820	17,472	83,000	804,709	0	0
August	3,064	51	807,722	108,871	18,848	42,000	746,874	0	0
September	1,438	24	748,288	108,895	14,384	31,000	702,904	0	0
October	545	9	703,440	108,904	10,024	13,000	680,416	0	0
November	5,534	33	685,917	108,937	6,688	7,000	672,229	0	0
December	18,883	223	690,889	109,160	4,243	0	686,646	0	0
Total for year	1,272,069	12,519	....	....	119,728	600,000	....	0	0
1904.									
January	16,840	199	703,287	109,359	3,041	0	700,246	0	0
February	18,902	111	719,037	109,470	3,090	13,000	702,947	0	0
March	6,060	36	708,971	109,506	10,441	54,000	644,530	0	0
April	0	0	644,530	109,506	10,241	119,000	515,289	0	0
May	0	0	515,289	109,506	13,149	119,000	383,140	0	0
June	0	0	383,140	109,506	11,672	119,000	252,468	0	0

Summary of data concerning the reservoir near Engle, N. Mex.

Year.	Inflow from river.	Silt deposited.	Lost by evaporation.	Used for irrigation.	Lost by overflow.	Water in reservoir at end of year.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1897	2,215,257	43,244	130,022	600,000	0	1,441,991
1898	964,677	15,413	236,210	600,000	0	1,555,045
1899	239,835	4,765	190,715	600,000	0	999,400
1900	484,324	9,539	149,419	600,000	0	724,766
1901	656,274	17,825	126,369	600,000	0	636,846
1902	200,729	5,855	84,896	600,000	0	146,824
1903	1,272,069	12,519	119,728	600,000	0	686,646
1904 (half year)	41,802	346	51,653	424,000	0	252,449
Total for 7½ years	6,074,967	109,506	1,089,012	4,624,000	0	....
Average per year	809,997	14,601	145,200	600,000	0	....
Percentage of inflow	....	1.8	18.0	76.2	0	4.0

Putting the last line of the summary in a different form it is found that during this seven and a half years the water that flowed into the reservoir would have been disposed of as follows:

Disposition of water at proposed reservoir near Engle.

	Per cent.
Loss by sediment	**1.8**
Loss by evaporation	**18.0**
Loss by overflow	**0.0**
Total loss	**19.8**
Water used for irrigation	**76.2**
Water in reservoir at end of 7½ years	**4.0**
Total	**100.0**

The foregoing tables for the proposed reservoir near Engle, N. Mex., show:

(1) That the accumulation of mud in the reservoir at the end of seven and a half years would be 109,506 acre-feet, which is at the rate of 14,600 acre-feet per year. It will therefore require eighty-two years to accumulate 1,200,000 acre-feet of mud, and fill up 60 per cent of the reservoir capacity, leaving a water capacity at that time of only 800,000 acre-feet, unless some means of getting rid of the mud is devised. This mud in the reservoir would have a depth of 150 feet, and its surface, as estimated from the table on page 411, would cover 25,516 acres, its surface dimensions being approximately 1⅓ miles wide and 30 miles long. The entire water space above this mud would have a maximum depth of 25 feet, and when full its surface would have an area of 38,000 acres.

(2) The tabulated statement shows that the reservoir will furnish continuously 600,000 acre-feet for irrigation without any deficiency and without any overflow.

(3) The largest amount of water there would have been in the reservoir at any time was in July, 1898, when there was 1,685,026 acre-feet of water; 168 feet being the maximum depth of water, including the mud. Hence, no water would have been lost by overflow with a 170-foot dam, or rather with a dam having a spillway for 170 feet depth of water, which spillway would be at elevation 4,380 feet, or 3 feet below the level of the lowest point of the gap selected for a spillway.

(4) The lowest quantity of water in the reservoir would have been 127,802 acre-feet at the end of April, 1903, and the depth in reservoir at that time 83 feet. The amount of water in the reservoir, June, 1904, at end of estimate, would have been 252,449 acre-feet.

COMPARISON OF THE TWO PROPOSED RESERVOIRS.

	El Paso.	Engle.
	Acre-feet.	*Acre-feet.*
Storage capacity	542,891	2,000,000
Yearly supply for irrigation (ordinary years)	180,000	600,000
Supply for irrigation in dryest year	176,381	600,000
Average annual loss by overflow	156,565	None.
Average annual loss by evaporation	122,293	145,200
Combined annual loss from evaporation and overflow	278,858	145,200

A given quantity of water stored in El Paso reservoir will have nearly twice the evaporation surface as the same quantity stored in Engle reservoir.

The El Paso reservoir would be filled with silt to 60 per cent of its capacity in forty-six years, as compared with eighty-two years for the Engle reservoir. After the reservoir had been filled to 60 per cent of its capacity there would still remain storage for 217,000 acre-feet in the El Paso reservoir and for 800,000 acre-feet in the Engle reservoir.

The efficiency of the two reservoirs can be seen at a glance from the following table, showing the percentage in each of the water supply lost by evaporation and overflow, and the percentage available for irrigation:

Record for seven and one-half years.

	Percentage of inflow.	
	El Paso reservoir.	Engle reservoir.
Loss by sediment	1.43	1.8
Loss by evaporation	24.55	18.0
Loss by overflow	32.00	.0
Total loss	57.98	19.8
Water used for irrigation	37.00	76.2
Water in reservoir at end of seven and one-half years	5.02	4.0
	100.00	100.0

The possibility of sluicing out part of the mud that accumulates and the corresponding effect upon each of the reservoirs may now be considered.

In order to be able to sluice mud from a reservoir the reservoir must be empty and the sluice water must come from some source other than the reservoir itself. Hence advantage must be taken of a natural flood in the river, or there must be an auxiliary storage dam above on the river or one of its tributaries for supplying sluice water. Without going into the question of the quantity of water necessary for this work, it will be assumed that it can be done by the method of ground sluicing used in hydraulic mining, a large tunnel being constructed at the bottom of the dam to provide the necessary outlet. A high-level canal along the hillside above the reservoir and a number of hydraulic giants undercutting the banks would materially increase the work that can be done by a given quantity of water, but for the present only the chance of ground sluicing with a large flow of water, without resort to pressure nozzles for undercutting the banks, will be considered, and it will be assumed, for purposes of comparison, that a single channel, having a width of 50 feet at the bottom and side slopes of 4 to 1, can thus be maintained through the mud from the upper end to the lower end of the reservoir. By referring to the foregoing statement it will be seen that the El Paso reservoir will accumulate sufficient mud in forty-six years to fill 60 per cent of its entire capacity, and the mud will have a depth of 46 feet in the river channel just above the dam and will extend upstream with a decreasing depth for a distance of about 13½ miles. Sluicing a channel through this mud along the center of the valley, with a width of 50 feet at the bottom and with side slopes 4 to 1, will remove 280,000,000 cubic feet of mud, which amounts to 6,428 acre-feet. But the rate of mud accumulation in this reservoir is 7,107 acre-feet per year. Hence the proposed sluicing would take out less than one year's accumulation.

It has also been shown that the Engle reservoir will accumulate sufficient mud in eighty-two years to fill 60 per cent of its entire capacity and that the mud just above the dam will be 150 feet deep and will extend upstream with decreasing depth for a distance of at least 30 miles. Sluicing through this deposit a channel with a bottom width of 50 feet and side slopes 4 to 1 will remove 5,353,920,000 cubic feet of mud, which is equivalent to 120,613 acre-feet. As the mud accumulates in this reservoir at the rate of 14,580 acre-feet per year, the proposed sluicing would remove the accumulations of eight and a fourth years.

This mud-sluicing discussion is not given to show the practical limits to which cleaning out by sluicing can be carried, nor is it here claimed that even the supposed channel can be maintained by sluicing; but the discussion applies the same hypothetical conditions to both reservoirs and shows that the same process applied to both will produce very different results. It takes out less than one year's accumulations of mud from the El Paso reservoir, while it removes more than eight years' accumulations from the Engle reservoir. This difference is due to the fact that in the former the mud is a wide, shallow deposit and in the latter it is a deep, narrow deposit. The same advantage will hold good for the Engle reservoir, no matter what process of sluicing may be applied or what the difficulties of sluicing the material may be, provided the material is the same in both reservoirs. The same process will take out nine-tenths of a year's accumulations in the El Paso reservoir and eight and one-fourth years' accumulations in the Engle reservoir. Sluicing is therefore nine times as efficient in the latter as the former. As the depth of mud in the latter is practically three times as great as in the former, the efficiency of sluicing appears to vary directly as the squares of the depths. This conforms to general principles and is a natural result of the investigations.

CONCLUSION.

The foregoing study has been confined to a comparison of the service that can be performed by the two proposed reservoirs. The question of cost has not been considered, but will be investigated later, yet it is safe to say that the El Paso reservoir would cost a great deal more in proportion to its efficiency than the Engle reservoir. The cost of the high dam of the Engle reservoir would be largely offset by the following conditions at the El Paso site:

(1) The greater depth to bed rock, and the fact that the bed rock is a broken limestone formation dipping downstream.

(2) The many thousand acres of rich, high-priced, Mesilla Valley lands to be submerged by water and mud by the reservoir or converted into marsh lands above the head of the reservoir.

(3) The removal of the railroad tracks occupying the land to be flooded.

(4) The flooding of the quarry and the removal of the manufacturing plants in the basin.

The El Paso reservoir would waste more water by evaporation and overflow each year than it would furnish for irrigation. It would produce in the immediate vicinity of El Paso many thousands of acres of mud flats and marshes on land that would otherwise be exceedingly valuable for agricultural and other purposes. It would furnish no water for irrigating the great Mesilla Valley in New Mexico, a region as truly tributary to El Paso as El Paso Valley itself, although it would waste enough water by evaporation and overflow to irrigate 83,000 acres.

On the other hand, the Engle reservoir will waste no water by overflow and a minimum amount by evaporation, and at the same time will furnish enough water for irrigation to supply Mesilla Valley, give a flow to the old Mexican canal equal to that which was used from it years ago for irrigation, and have enough left over to allow Texas to participate in the benefits.

The Engle dam has the final advantage of being in New Mexico and subject to the reclamation act. The project can be so planned that legislation by Congress can allow Mexico and Texas to participate. But the extent and manner of this participation is a matter that must be arranged and decided by Congress and the Department of State. All that the Reclamation Service can do at present is to make plans and estimates for work in the Territory of New Mexico that will not conflict with any action that may be taken by Congress and by the Secretary of State for restoring water to which El Paso Valley has laid claim in Texas and Mexico by virtue of ancient prior appropriation and continuous use.

RIO GRANDE PROJECT

GENERAL CONDITIONS.

The foregoing discussions have brought out certain facts concerning the Rio Grande that can not be neglected in making a general plan for storing its flood waters and irrigating its rich valleys. The Rio Grande is essentially a torrential or storm-water stream, subject to great floods, so irregular in their occurrence that the total flow in some years is less than one-tenth of the total flow in other years. As all of this water is much needed for irrigation a reservoir that will waste a large amount of it by overflow or by unnecessary evaporation is not to be considered. The quantity of water required might be stored in a series of reservoirs along the river, having a combined capacity sufficient for impounding all the flood water; but the cost per acre of land irrigated would be too great. The depth from the present river bed to bed rock is from 65 to 90 feet at nearly all of the available reservoir sites. As all the dams, whether large or small, must be founded on bed rock, a series of small dams will cost more than one large dam forming a reservoir with a storage capacity equal to that of all the others. But aside from the increased cost of storage by means of a number of small reservoirs, there is another condition that absolutely prohibits their use. The Rio Grande is a very muddy river. It carries in suspension a percentage of silt that varies from year to year, and from month to month, but that is sufficient to have made a mud deposit in the last seven and one-half years equivalent to 1.8 per cent of the total volume of water that has come down the river.

Any reservoir constructed on the river will stop all the silt that comes down the river in suspension. A small reservoir will accumulate as many acre-feet of mud per year as a large one, until it is filled with mud. With a series of small reservoirs the upper one would fill with mud in a short time, and any mud that might be sluiced out of it would simply be transferred to the next one below, and so on. It has also been shown that any process of mud sluicing that can be resorted to is much more efficient in a large, deep reservoir than in a smaller, shallow one.

It therefore appears that the best solution of the mud question, as well as the storage question, is the construction of one big reservoir of great depth, with a capacity to store all the water and equalize the irregular flow over a number of years, and with surplus capacity for mud storage, until posterity can take advantage of its great depth to sluice it out economically.

A general map of the proposed Rio Grande project is shown on Pl. XLVII.

ENGLE DAM.

So far as known the only site for such a dam and reservoir on the river is the site selected by the reclamation engineers below Elephant Butte, near Engle, N. Mex. If the plans are carried out successfully at this site, the reservoir will not only meet all of the demands for irrigation below it, but will protect the valley below from the disastrous floods to which it is now subject.

IRRIGABLE LANDS.

The following is a statement of the irrigable lands of Rio Grande Valley in the United States immediately below the proposed dam:

Irrigable lands surveyed in New Mexico and Texas below the proposed Engle dam.

	Acres.
Below Engle dam to United States dam site No. 39:	
East side of river, survey by Reclamation Service	2,949
West side of river, survey by Reclamation Service	6,913
Below dam site No. 39 to Rincon:	
East side of river, land-office maps	6,400
West side of river, land-office maps	15,240
Below Rincon to Penasco Rock:	
East side of river, land-office map	5,230
West side of river, land-office map	3,560
Below Penasco Rock to Texas State line:	
East side of river, Reclamation Service	52,879
West side of river, Reclamation Service	25,152
Below Texas State line to El Paso, Tex.:	
In Mesilla Valley, Reclamation Service	22,227
Below El Paso, Tex., on east side of the Rio Grande, to town of Rio Grande	71,800
Total	208,400

SPECIFICATIONS FOR DAM.

The Engle dam, as projected by this survey, will be arched upstream and on a 6° curve, the upstream edge of the crest having a radius of 955 feet. The dimensions are as follows:

Height from bed-rock foundation to top of parapet walls on crest, 255 feet.

Height from river bed (sand) to top of parapet walls on crest, 190 feet.

Thickness at bottom, 180 feet.

Thickness at crest from outside to outside of parapet walls, 20 feet.

Length of crest, 1,150 feet. Length of dam at river level, 400 feet.

From upstream edge parapet wall of crest a triangular section gives upstream batter 1 inch to the foot; downstream batter, 7½ inches to the foot.

Downstream edge of crest 3 feet 6 inches vertical and curved to meet the downstream batter with a 100-foot radius.

Roadway 5 feet below crest between parapet walls on each side and 14 feet wide.

Height of spillway, 10 feet below roadway of crest and 15 feet below top of parapet wall.

Depth of water from river bed to spillway, 175 feet.

Strains calculated for possible high water at crest 255 feet above foundation, with weight of masonry 141 pounds per cubic foot, or a specific gravity of 2.25.

Spillway to be at a gap on west side of valley several miles above the dam. This spillway will be 175 feet above the level of the present river bed at dam site, and will have a length of 800 feet.

The reservoir will be about 40 miles in length, and will have a storage capacity of 2,000,000 acre-feet to the level of spillway. It will furnish about 600,000 acre-feet per annum for irrigation, and will irrigate 180,000 acres of land.

If no means of keeping the mud cleared out is provided, it is estimated that the silt deposits in the reservoir will decrease its capacity 60 per cent in eighty-two years, but a proper sluice tunnel and gates will make it possible to take advantage of conditions and opportunities for getting rid of mud by sluicing. The necessary conditions are an empty reservoir and a flow of water through the reservoir bed, either from a natural flood in the river or from an auxiliary reservoir above provided for the purpose.

All that is necessary at present is to construct an ample opening at the river level with gates that can be operated when the reservoir is empty.

The openings for everyday use will consist of a sufficient number of cast-iron pipes with proper gates on them.

Some of the large cast-iron service pipes will have their inlets in the vicinity of the large sluice gate, so that this large gate will not be covered with mud.

Another set of pipes will come through the rock bluff at the opposite end of the dam and will lead to water wheels, if it is found to be profitable to produce power in this way.

As bed rock is about 65 feet below the present river bed, it will be necessary to excavate about 65 feet of sand and gravel to get the dam on bed rock.

Although the river was practically dry for three months in 1900 and for five months in 1904, it will be necessary to provide a flume or other waterway that will carry the whole river and keep it out of this excavation; also strong cofferdams and a large pumping plant. The sand must be excavated by pumping, or by an elevator dredge, or by cableway excavators. By a system of driven wells all around the inside of the cofferdam it is probable that the sides of the excavation can be kept dry enough to maintain a slope of 3 to 1 in an open cut, but in this estimate a slope of 4 to 1 is assumed.

Schedule of quantities for dam.

44,400 cubic yards soft rock and earth excavation along hill slopes.
335,000 cubic yards sand excavation.
Cofferdams above and below, 400 feet each.
Flume or waterway for river, 800 feet long.
5,000 cubic yards bed-rock excavation for dam anchorages.
114,000 cubic yards of cyclopean concrete below river bed.
296,000 cubic yards cyclopean concrete above river bed.
Tunnel and sluice gates and outlets.
Paving for spillway.
Earth excavation for spillway, 120,000 cubic yards.
Foundation for spillway.
Soft rock excavation for spillway.
Concrete masonry for spillway, 2,000 cubic yards.

No railroads and but little good land will be submerged by this reservoir.

DIVERSION DAM AND CANAL.

Plans and specifications have been prepared for a diversion dam at Penasco Rock, near Selden station on the Santa Fe Railroad, about 18 miles above Las Cruces, N. Mex.; and for 7 miles of canal from that point to the head of the present Las Cruces canal. This spot has generally been considered the proper one for this diversion dam, as the large solid rock protruding from the left bank and extending about 50 feet into the river offered a safe abutment for a dam and anchorage for canal gates, notwithstanding the fact that borings in the river bed opposite this point of rock show a depth of 70 feet to bed rock. But Survey plans and estimates show that its advantages are more than counterbalanced by its unfavorable location. Some of the unfavorable conditions are as follows:

(1) The Santa Fe Railroad occupies the only ground that would be available for a canal in the first 2,600 feet below the rock. It will therefore be necessary either to move the railroad farther back into the hill at a great expense or to build the canal in the river bed by constructing a high embankment and protecting the embankment against the scour of the river.

(2) The elevation gained by starting the canal at Penasco Rock can not be maintained except at great expense, and if it could be kept up at a regular grade the water would be on a higher level than is necessary to cover the agricultural lands.

(3) The high, soft river bluff for one-half mile above the mouth of Las Cruces canal is undermining and encroaching on the railroad to such an extent that there is not room for a canal between the river and the railroad, and the ground is entirely too high for a canal above the railroad. It will therefore be necessary to drop nearly to the river level and use the present river bed for a canal at this point. In order to do this the river can be turned across the big bend by a cut-off along the west side of the valley. This will put the river channel at least a mile west of its present location and get it out of the way.

The above practical considerations have developed the fact that Penasco Rock is 4 ar 5 miles farther up river than is necessary to go for a diversion, and that, aside from this extra length of canal, it will be cheaper to make a diversion dam lower down the river, where there is no rock bluff, as the difficulties encountered in building the first 2,600 feet of canal more than counterbalance the advantages of the rock abutment.

NEW DIVERSION POINT.

The above considerations have led to the selection of a new diversion point on the river, opposite the residence of Mr. Summerford, at Leasburg station, on the Santa Fe Railroad, about 5 miles below Penasco Rock. At this new site the river is on the west side of the valley, against the foothills. The site is about 2 miles above the proposed cut-off, across the big bend. The cut-off will cause the river channel to lower at least 5 feet at the site, and will make the banks comparatively high.

Here can be constructed a diversion dam similar in every way to the proposed Penasco Rock diversion dam, except that a concrete pier will take the place of the natural rock. The canal will also have a similar head weir and head-gates. From the Leasburg diversion dam (as this site will be called for distinction) 2 miles of canal will reach the point where it is proposed to use one-half mile of the present narrow river bed above the mouth of the Las Cruces canal.

Following is a schedule of the work for the Leasburg diversion dam, sluice gates, canal inlet, and 2½ miles of canal leading to head of the Las Cruces canal:

Structures of Leasburg diversion and conduit to Las Cruces canal.

500-foot concrete weir dam, with pier, embankment, and sluice gates.
Pier at left bank.
Inlet to canal.
Head-gates in canal.
Concrete in head-gates, wing walls, and floor.
2 miles of full-size canal, with 146,000 cubic yards of earth excavation.
River cut-off at Big Bend, 24,000 cubic yards earth excavation.
Embankment across river above cut-off, 10,000 cubic yards.
Wire fencing for river control.
Right of way.
Sluice gates in embankment above mouth of Las Cruces canal.
Arroyo control, drop, lower embankment, etc.
Watchman's house.

The above schedule includes a canal large enough for 1,000 second-feet. A present capacity of 500 second-feet will be sufficient for furnishing water from the river to existing canals in the valley while the Engle storage dam is in construction.

REPORT OF BOARD OF CONSULTING ENGINEERS.

The board of consulting engineers reported on this project as follows:

> The considerations which prompted the investigations for a high dam near Engle as superior to the international dam project have been signally justified by the results, which may be summarized as follows:
>
> 1. The proposed Engle reservoir has a capacity of 2,000,000 acre-feet, as

against about 540,000 acre-feet that can be provided by the proposed international reservoir at El Paso.

2. The former will furnish for irrigation 600,000 acre-feet of water per annum, while the latter will furnish only 180,000 acre-feet.

3. The former will lose no water by overflow, while the latter will waste a very large percentage by overflow.

4. With a given amount of water the Engle reservoir will present only about one-half the surface for evaporation that will be presented by the international reservoir.

5. It will probably require eighty-two years to fill 60 per cent of the former reservoir with mud, while the latter reservoir will be filled with mud to 60 per cent of its capacity in forty-six years.

6. The Engle reservoir is deep and narrow, while the International reservoir is wide and shallow, and in consequence it is found that any process of sluicing out mud will be nine times as efficient in the former as in the latter.

7. The Engle reservoir will store the entire flow of the river without waste and with a minimum evaporation, and will prevent disastrous floods along the valley occupied by the Santa Fe Railroad and by several important towns, while the International reservoir will waste the water by overflow, present conditions producing a maximum of evaporation, regulate no floods above El Paso, cover 25,000 acres of good land near El Paso, and make marsh land of probably 15,000 more above it, and produce insanitary conditions at El Paso.

8. The International dam proposes to destroy about 40,000 acres of good land immediately north of El Paso in order to irrigate about 55,000 acres below El Paso, while the Engle reservoir proposes to irrigate the 40,000 acres of land that the other would destroy, also to irrigate 50,000 acres below El Paso, and, in addition, to irrigate 90,000 acres above in New Mexico, a total of 180,000 acres, all of which is tributary to El Paso.

A study of the water supply of the Rio Grande as measured at San Marcial, regulated by the proposed dam below Elephant Butte, shows that 600,000 acre-feet of water could have been drawn from the reservoir each year without ever emptying the reservoir. This is a basis for estimating the future duty.

At the rate of 3⅓ feet in depth for irrigation the water would serve 180,000 acres. The surveys show irrigable land about as follows:

	Acres.
Above Penasco Rock	40,000
Penasco Rock to Texas line	70,000
In Texas above El Paso	20,000
In El Paso Valley below El Paso	50,000

According to the above figures the Engle dam would furnish water to 110,000 acres of land in New Mexico and 20,000 acres in Texas, or a total of 130,000 acres of land above El Paso, and a surplus of water sufficient for 50,000 acres, which could be emptied into the river for use below El Paso.

The cost of the project, including the reservoir and all diversion works and canals above El Paso, is estimated at $7,200,000, or $40 per acre on 180,000 acres. This is below the value of irrigated land in this valley, and those best informed pronounce the project desirable at this price. The main item of cost is the dam, and this will require about 300,000 barrels of cement.

The people in Las Cruces were informed of the result of the investigations at a public meeting, at which a resolution was unanimously adopted declaring in favor of the project and requesting the board to recommend legislation by Congress to enable lands in Texas to benefit by the reservoir and contribute to its cost.

The land to be irrigated is nearly all private land.

Prominent citizens of the valley assert that there is little doubt that practically all the owners of land in the valley will readily comply with the provisions of the law by which they may receive the benefits of the reclamation act, and the board concurs in this opinion. An organization to take in hand the subject of securing pledges of land to the cost of the project has been recommended, and it is not feasible to begin construction until these are secured, but the prospects are sufficiently good to justify a recommendation that legislation be asked that will authorize the irrigation of lands in Texas in connection with the project.

THE ROSWELL ARTESIAN BASIN, NEW MEXICO.[a]

Flowing wells were first obtained in the Roswell artesian basin about ten years ago, and for a number of years development was confined chiefly to the immediate vicinity of Roswell. During the last two years, however, a number of strong flows have been obtained near Artesia, a small town about 40 miles south of Roswell, and at present this part of the basin is experiencing the greatest development. There are now over 40 well machines at work in the region, many of which are of the most improved type. It requires from one to two months to complete an average well, so that from the above figures an approximate estimate can be obtained of the rate at which development in well boring is going on throughout this district.

The Roswell artesian basin is 60 miles long and has an average width of about 10 miles. It has an area of between 600 and 700 square miles, the greater part of which lies along the west side of Pecos River in southeastern New Mexico. Owing to the rapidity with which wells have been drilled throughout this region it is difficult to give a complete list of the flowing wells, but records have already been obtained of over 200, and it is probable that the total number exceeds 300. More than half of this number are found in the extreme north end of the basin at Roswell and the North Spring River Valley. The flow of these wells varies from a few gallons to 1,800 gallons a minute, depending principally on the locality. At Roswell the flow of an average well has been variously estimated at from 500 to 700 gallons, while near Artesia the highest flow recorded exceeds 1,700 gallons. The water is used chiefly for irrigation and domestic purposes. In a few cases it is unfit for domestic purposes on account of the presence of sulphur. The water from Formwaltz well, northwest of Hagerman, is said to have medicinal properties, although no chemical analysis was obtained. Considerable interest has always been shown in the composition of the Roswell artesian waters, and a few years ago extended analyses were made by Prof. E. M. Skeats, of El Paso, Tex. Unfortunately the material is not available at the present time. Generally where wells are utilized for irrigating purposes the water is taken from the well directly to the field, or temporarily stored in small reservoirs. In a few cases, however, wells have been constructed along the side of the larger canals in order to increase the flow. On the margin of South Spring Lake, the head of South Spring River, several shallow wells have been sunk, which materially increase the flow of this stream.

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[a] From report by C. A. Fisher.

CHARACTER AND AGE OF THE ROCKS.

The rocks of the district comprise limestone, sandstone, clay, and gypsum, which are believed to be of Permian age. Overlying these deposits are extensive sheets of sand, gravel, clay, and silt of the Quaternary period, deposited in successive terraces between the Pecos River and the high limestone slopes to the west. For convenience in the present discussion, the Permian beds of this district may be divided into three groups—the upper gypsum beds forming the high bluffs along the east side of the river, the red sandy series underlying the Recent deposits in the Roswell basin, and the massive limestones comprising the rugged slopes to the west. The upper gypsum series consists of alternating layers of gypsum and red sandy clay, in which gypsum generally predominates. Near the top an occasional limestone bed is encountered. This group has an average thickness of about 300 feet, the beds ranging from 6 to 10 feet in thickness. The red sandy series consists chiefly of red sandstone and clay, although layers of gypsum and limestone are not uncommon. The sandstones are porous and incoherent, while the clays are impervious. Near Artesia the entire series has a maximum thickness of 600 to 700 feet, but to the north is much thinner, especially in the vicinity of Roswell, where it scarcely exceeds 100 feet. The underlying massive limestones reach a very great thickness in this general region, but it is only the uppermost member, a porous, sandy limestone, which need be considered.

WATER HORIZONS.

There are several distinct artesian horizons in the district, nearly all in the Permian series. The strongest flow is from a gray, porous limestone, which is rather thin bedded and contains many sandy layers. This limestone varies in thickness from 30 to 60 feet, and is the uppermost member of the massive limestone beds of the lower Permian. Above this horizon several smaller flows occur at varying intervals throughout the overlying red sands and recent deposits.

SOURCE OF SUPPLY.

The water-bearing formations outcrop successively on the slope to the west, where they receive their water supply by direct absorption from rainfall and surface streams. The Hondo, Felix, and Penasco are the most important sources. These streams all rise high on the slopes of the El Capitan, White, and Sacramento mountains, where the rainfall is relatively large. As a result they carry an abundance of water in their upper courses, all of which sinks in the outcrop zone of the porous, sandy limestone and the overlying sandy series, and passes underground eastward. After the water has entered these porous formations, it is confined by impervious layers of limestone or clay and, under the lower lands eastward, is under considerable pressure.

DEPTH OF WELLS.

The wells of this district vary in depth from 50 to 900 feet, the shallowest ones occurring in the low valley lands east of Roswell. To the south the main flow is reached at a much greater depth, due to the presence of higher beds in the Permian. At Roswell the average depth varies from 200 to 300 feet, while near Artesia the same flow is obtained at a depth of 800 to 900 feet.

PRESSURE MEASUREMENTS.

In connection with the recent investigation of the geology and underground water relations of the Roswell artesian basin, a systematic measurement of well pressures has been carried on. At the time when this investigation was proposed there appeared to be no evidence of a decrease in flow, but it was evident that the multiplicity of wells within so limited an area would eventually lower the water plane unless greater economy was practiced on the part of the water users. In arranging for the work, a number of representative wells were selected at different points throughout the basin—four from Roswell, where many wells have been sunk in a relatively small area, and others from near Hagerman and Artesia, points farther south. In making these selections, care was exercised to obtain only those which were believed to be representative of local districts and in perfect condition. In a few instances, however, defective pipes were discovered after the first monthly pressure had been recorded. Careful measurements were taken of these wells each month, under uniform conditions, as far as possible. The result of this investigation, extending over a period of six months, is shown in the following table:

Pressure measurements of artesian wells in the Roswell artesian basin, New Mexico.

Owner	Location.	District.	Pressure.						Remarks.
			June.	July.	Aug.	Sept.	Oct.	Nov.	
			Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	
R. M. Parsons	Lot 4, block 54, west side additional NE. ¼ SE. ¼ sec. 32, T. 10 S., R. 24 E.	Roswell	7	7	7	7	7	7	Casing of well apparently in perfect condition.
Dr. C. M. Yater	Lot 7, block 26, original town site, NE. ¼ SE. ¼ sec. 32, T. 10 S., R. 24 E.	...do...	7	7	7	7	7	7	Do.
R. S. Hamilton	Lot 12, block 14, original town site, SW. ¼ SW. ¼, sec. 33, T. 10 S., R. 24 E.	...do...	6½	6½	7½	7	7	7½	Do.
P. V. and N. E. R. R. at roundhouse.	NE. corner NW. ¼ SW. ¼ sec. 33, T. 10 S., R. 24 E.	...do...	12	10	12	12	12	12	Slight leakage in casing near surface and at valve caused a decrease of pressure in July measurement.
M. E. McClenny	SE. ¼ SE. ¼ sec. 35, T. 10 S., R. 24 E.	...do...	16½	16½	20	20	20	21	Low pressures in the months of June and July due to leakage in pipe.
E. P. Rasmussen	SW. ¼ NW. ¼ sec. 21, T. 11 S., R. 25 E.	...do...	31	31	31	31	31	32½	Casing of well apparently in perfect condition.
J. J. Hagerman	About center of the west line of NW. ¼ SE. ¼ sec. 13, T. 11, R. 24 E.	...do...	13	13	13	13½	13½	13½	Do.
Greenfield Farm	Center of sec. 32, T. 13, R. 26 E.	Hagerman.	58	58	57	57	55	53½	This is an old well and the casing may be defective.
J. C. Hale	NW. ¼ SE. ¼ sec. 15, T. 17 S., R. 26 E.	Artesia.	88	87	87	84	84	82	Decrease in pressure may be due to escape of water into a higher artesian horizon, which is reached by a shallow well not far away.
Hodges & Venable.	Middle of west line of SE. ¼ NW. ¼ sec. 23, T. 18, R. 25 E.	...do...	31½	31½	30½	30	29	27	Slight leakage at valve during last measurement.
J. B. Gilliland	SW. cor. SE. ¼ sec. 19, T. 18, R. 26 E.	...do...	83	82	80	79	80	79	Casing of well apparently in perfect condition; slight leakage in valve.
Dr. A. L. Norfleet.	NW. cor. of S. ½ NW. ¼ sec. 32, T. 17, R. 26 E.	...do...	......	......	62½	61	61	58	Slight leakage at valve during first and last tests.
John Richey	SW. ¼ NE. ¼ sec. 14, T. 16 S., R. 26 E.	...do...	......	......	......	......	......	95½	Slight leakage at valve.

In most cases where the wells were in perfect condition the pressures appear to be satisfactorily accordant, but in a few instances a perceptible decrease is noted, particularly in the vicinity of Artesia, where some of the strongest pressures are reported. Without a knowledge of the existing physical conditions around Artesia, the decrease in pressure of some of the largest wells in that vicinity might at first appear alarming, but a comparison of this district with the Roswell district, where there is apparently no decrease, introduces many important factors which have a direct bearing on the case.

At Roswell the artesian water is obtained at a depth rarely exceeding 250 feet, and the materials passed through offer practically no difficulty; as a result, very perfect wells are constructed. Then, too, in this region wells have been built for the last decade, and the well driller is so familiar with the conditions that he can predict with a fair degree of accuracy the materials to be encountered in sinking a well. Farther south in the basin, in the vicinity of Artesia, a successful artesian well is not so easily obtained. Here the main flow is reached at much greater depths, ranging from 600 to 800 feet, depending on the location. This increased depth is due, as above stated, to the presence of higher beds in the red sandy series of the Permian. In this formation, consisting of alternating layers of red sandstones, clay, and gypsum, the sandstones predominate. These are of loose texture and are familiarly known to the well driller as quicksand. This material is very difficult to drill through, owing to caving, and in one or two instances it was so troublesome that the owner was compelled to abandon the project. The pressure at the surface in the Artesia wells is about 85 pounds to the square inch, which means about 450 pounds to the square inch at the bottom of the well where the water is first encountered. Forces of this character are difficult to manage, particularly where exploitation in the region has not been sufficiently extensive to enable the well driller to thoroughly acquaint himself with the nature of the obstacles to be encountered and make suitable provision for them. The region offers considerable inducement to the ambitious well driller, and, as a result, new machines are constantly coming into this field, and with them as operators men who, though skilled in the art of well drilling, are entirely unfamiliar with this locality. It can readily be seen that under these circumstances imperfect wells are likely to result. Some of the strongest flows in the basin are and have been unmanageable since the completion of the wells, while others are not working satisfactorily owing to unfavorable conditions. In selecting wells for systematic measurement, as above stated, care was exercised to take only those that were in perfect condition, but this was difficult to do, and some that were at first supposed to be in perfect condition proved later to be defective. It is not unlikely that continued investigation along this line may reveal defects in construction of some of the wells that now show a decrease in pressure.[a]

WASTE OF WATER.

There is a pressing need for greater economy on the part of the users of well water throughout the Roswell basin. At Roswell there is a city ordinance regulating the management of all flowing wells, but throughout the remainder of the district no restraint whatever is placed upon the management of the wells, and, with very few exceptions, they are allowed to flow continuously. A relatively small portion of this water is stored in artificial reservoirs, but by far the greater part runs off into pools, evaporates, and seeps away on uncultivated lands, or runs directly into Pecos River. In one case a ditch leads from the well directly to the river, a distance of one-half mile, and it is not an unusual thing to find water flowing from wells to low, marshy lands adjacent to the river, where by underflow it soon reaches the main channel. Formerly many of the wells were not even furnished with reservoirs, and the water was carried by laterals from the wells directly to the field during the irrigating season, and at other times allowed to flow off through a wasteway. Nearly all of the wells that are being constructed at the present time in the south part of the basin are to be furnished with reservoirs, ranging in capacity from 6 to 24 acre-feet, which are filled as often as necessary during the irrigating season. Even these commendable provisions are quite ineffectual in the case of wells not provided with valves, as they conserve only a relatively small portion of the total flow. An effort is now being made by a few of the well owners in the vicinity of Artesia to provide the wells with suitable valves, so that when the water is not in use and the reservoir is full the flow can be shut down. There is a general prejudice among well owners against shutting off the flow, fearing that it may decrease the efficiency of the well. It is true that in a few cases wells have been damaged in this way, but the proportion injured, if properly constructed, is very small.

Stream measurements of the Pecos River for 1903, taken at the point where this stream merges into Lake McMillan, which is at the lower end of the Roswell basin, show an increase of 25 per cent over the flow of the previous year. As last season was a particularly dry year, it seems reasonable to attribute part of this increase to water from artesian wells in the Roswell basin.

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[a] Since preparing this article for publication additional evidence has been received, which strongly indicates a general decrease in pressure of flow in the vicinity of Artesia, N. Mex.

OPERATIONS IN NORTH DAKOTA.

By F. E. Weymouth.

FORT BUFORD PROJECT.

The Fort Buford project, containing 66,000 acres of land, is situated in northeastern Montana and northwestern North Dakota, along the left or west bank of Yellowstone River, extending from a point 20 miles north of Glendive, Mont. (the Yellowstone has a northerly course through the project), to a point opposite Buford, N. Dak., on Missouri River. The land all lies at an elevation between 1,850 and 1,980 feet. The portion situated in North Dakota was at one time a part of the Fort Buford Military Reservation. The sum of $1,200,000 has been provisionally set aside from the reclamation fund for the construction of this project.

Water is to be taken from Yellowstone River at a point about 2 miles below the mouth of Thirteenmile Creek and 19 miles north of Glendive, Mont., the nearest railway station on the Northern Pacific, this being the most feasible point on Yellowstone River at which to build a diversion dam and head-gates for a canal to cover the lands in this project. It is not practicable to take out a canal above this point, since the badlands come in against the river for a stretch of several miles. These are traversed by numerous wide and deep creeks, which occasionally carry large floods, and which would be very expensive to cross, to say nothing of the deep cuts through the high banks.

Below this point the west bank is low and very unstable, and it would be difficult to protect the head-gates against the eroding action of ice. Besides this, grade would be lost, which is an especially important factor. At the point of diversion adopted the river is rather shallow and has suitable foundations for a low diversion dam. The dam can be so located as to permit the canal to be taken out in a tunnel, thus placing the head-gates where they will be well protected from the shock of large ice gorges, which cause considerable damage along this river every few years. Stone for construction purposes is near at hand.

AREA TO BE IRRIGATED.

The irrigable land is situated on the left or west bank of the Yellowstone in a strip 65 miles long and 5 miles wide at the widest point.

A large portion of the land lies in benches covered with grass; the remainder is low bottom land covered with trees, rose bushes, and sagebrush. Alkali does not appear on this project except in a few places.

The soil of the bench land is sandy loam 4 to 10 feet deep, underlain with a thick stratum of gravel. The benches have an even slope, sufficient to drain well, and are so smooth that very little preparation will be required before water is supplied.

The soil of the bottom land is mostly sandy loam, but in certain localities is of a clayey nature. This land will require grubbing and leveling before water is applied, but this can be cheaply done. After water is applied to the bench lands it is probable that some of the bottom lands will require drainage.

This project is in the semiarid region, so the years of ample rainfall are very infrequent. On such years abundant crops of grains and vegetables are raised, the soil being peculiarly well adapted to potatoes and forage crops. These lands are largely private holdings, and where watered small fruits are profitably grown.

The project is surrounded by one of the largest and finest grazing regions in the West. The stock requires feeding during three months of the year, and the quantity of feed available determines the amount of stock that can profitably be raised. With this tract of land irrigated, alfalfa and other forage crops can be grown extensively, making this one of the largest stock-feeding points in the West.

WATER SUPPLY.

The amount of water required for this project will be about 830 second-feet. The lowest discharge measurement yet taken of the Yellowstone at Glendive is 5,966 second-feet. This was with a gage reading of 1.45 feet. During low-water years the gage sometimes reaches zero in August, which is in the irrigating season, and at that time the Yellowstone must be discharging at least 2,500 second-feet. So the water supply is more than ample without resorting to storage.

DUTY OF WATER.

Irrigation has been used very little in North Dakota and eastern Montana, and no study of the duty of water has been made. Therefore this point is rather problematical. A few gardens are irrigated from small creeks, but no data are obtainable in regard to them. If the lands are well saturated in the spring from the melting snows, a fair crop can be raised, providing one or two days' rain occurs in May and again in July. This shows that the soil retains the moisture remarkably well, and it is believed that 1 second-foot of water delivered on the land will irrigate 100 acres and that the loss from seepage and evaporation in the canal will not exceed one-half of 1 per cent per mile.

RAILROAD FACILITIES.

This project, located as it is between Yellowstone and Missouri rivers, is not at present easily accessible from any railroad. Glendive, the nearest station on the Northern Pacific Railway, is 20 miles from the head-gates and on the opposite side of Yellowstone River. Buford, the nearest station on the Great Northern Railroad, is only 2 miles from the lower end of the project, but is on the opposite side of Missouri River, which is crossed by a steam ferry. Owing to sand bars in the river, and to low, soft ground on either bank, ferrying is very difficult.

There is a wagon bridge across the Yellowstone at Glendive, and an excellent wagon road, with easy grades, runs to the head-gates and thence the entire length of the project to Buford, N. Dak.

Although a railroad is greatly needed in this valley, the lack of it is not so greatly felt as would at first seem evident, since the crops that are best suited to the soil and climate are forage crops, which can all be fed to stock where raised.

PROGRESS OF WORK.

This project was first visited in July, 1903, by F. E. Weymouth and J. N. Kerr. As considerable irrigable land was found in Montana, as well as in North Dakota, and as Yellowstone River furnishes an ample water supply for the land in both States, it was recommended that a preliminary survey be made, starting at Terry, Mont., 40 miles above Glendive, to determine if all the land in Yellowstone Valley from that point to the Missouri could be reached by a gravity canal. Surveys for this purpose were begun in August, 1903.

It was soon found that the light fall of the Yellowstone and the high elevation of the land above the river made it impracticable to cover any land above Glendive. So the surveys for a canal heading at Terry were dropped and another survey was begun for a canal heading 2 miles above Glendive. This line was continued to Missouri River and covered some 70,000 acres of land. From this survey estimates were worked up, and it was found that the cost of irrigating the 70,000 acres covered would be about $40 per acre, a price which was deemed excessive.

By the use of the topographic map a rough estimate was worked up for a low-line canal heading about 19 miles below Glendive. The results of these estimates were such as to justify further investigation, and in April, 1904, a board of consulting engineers consisting of A. P. Davis, J. H. Quinton, B. M. Hall, and C. H. Fitch visited the project and left instructions to have the canal surveyed, the amount of land under it ascertained, and a preliminary estimate of cost worked up.

The following table shows the number of acres of public, private, and railroad lands under the project:

Estimate of lands under Fort Buford project.

	Montana.		North Dakota.		Total.	
	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.
Private lands	14,618	35.4	12,786	55.8	27,404	42.7
Public lands	12,556	30.5	10,109	44.2	22,665	35.4
Railroad lands	14,075	34.1			14,075	21.9
Total	41,249		22,895		64,144	

After the estimates were completed J. H. Quinton, consulting engineer, visited the project, examined the plans and estimates, and gave instructions to obtain all the information necessary for detailed estimates and plans preparatory to letting contracts for building the necessary works.

DIVERSION DAM.

Yellowstone River from the point of diversion to its mouth has an average fall of 2.2 feet per mile. Much of the land to be irrigated in this system lies in benches 90 feet above the river, and in order to reach it with a canal it is necessary to raise the water in the river at the head-gates by means of a diversion dam and to build the canal on as light a grade as possible.

On the canal side of the proposed diversion dam the bank rises 50 feet above the water surface of the river. On the opposite side, however, the bank is low, being but 15 feet above low water and extending back nearly level for about 2 miles to high bluffs (see Pl. XLVIII). This level tract is an island during high water, being separated from the high bluffs by a channel of the river. This entire area has been mapped on a scale of 200 feet to 1 inch with 2-foot contour intervals, and a study made of the site. The conclusion reached is that it will not be safe to build a dam at this point which will raise the low-water stage more than 5 feet.

Borings at the dam site have been made in order to determine the best type and cost of this diversion dam. The borings show that the river bed is a hard, stiff clay for a depth of at least 50 feet—the greatest depth to which holes have been driven. This material is excellent for holding piles. It is probable that the best and most economical construction for a dam at this place will be to drive several rows of piles across the river, fill in between them with large stone, and then cover the face with timber, giving the upstream face a slope of 3 to 1 and the downstream face a slope of 6 to 1. It is believed that the ice will easily slide over this type of structure.

SILT IN THE CANAL.

The canal will have a capacity of about 830 second-feet and a grade of 1 in 10,000. In order to obtain as great a velocity as is possible with this low grade the canal will be built narrow and deep and so obtain as great a hydraulic mean radius as possible. By doing this a velocity of 2.1 feet per second can be obtained.

The Yellowstone carries much silt and has a velocity of from 4 to 10 feet per second, depending upon its height. When this high velocity in the river is suddenly changed to 2.1 feet per second in the canal a large amount of silt will be deposited, chiefly in the upper portion of the canal, which will have to be cleaned out at least once a year, as it is not possible to put in a settling basin. Sluice gates will be placed in the dam, and it is probable that a large portion of the silt can be sluiced through the dam and prevented from entering the canal.

CANAL LOCATION.

About 25 miles of the canal will be in very rough country, and the work is exceedingly heavy. There are 13 difficult creek crossings to be made, one of which will be made with a concrete-steel pressure pipe 3,000 feet long and 10 feet in diameter. With the exception of a few hundred yards the material excavated from the canal will all be earth.

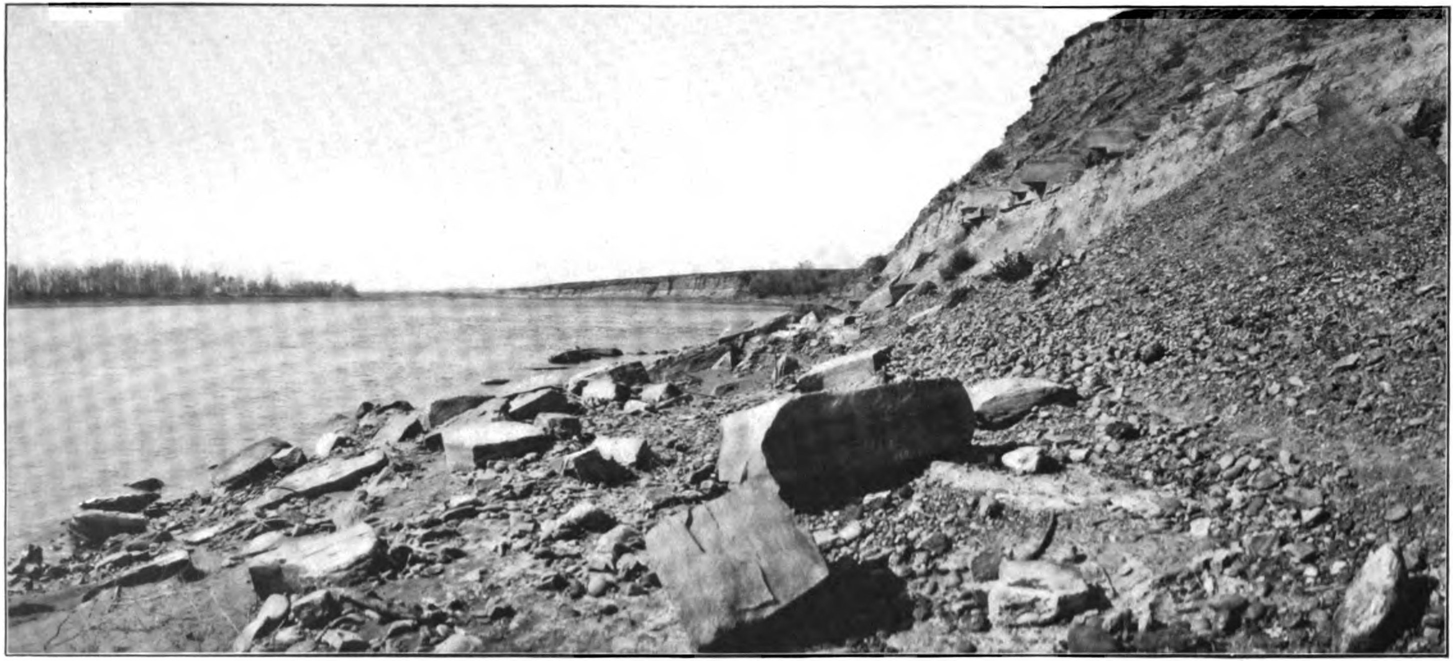
PUMPING.

The main canal will follow the side of a deep bench for about 12 miles. Below this bench is a large amount of land which will require water. Hence it is proposed to drop water through a turbine wheel to this land and at the same time furnish power with which to pump water from the main canal to the land at the top of the bench. From 3,000 to 6,000 acres of land can be watered in this manner.

The conditions are such that a centifugal pump directly connected to a turbine wheel can be installed. By using this method of pumping the greatest possible efficiency can be obtained and the cost of maintenance reduced to a minimum.

BORINGS AND TEST PITS.

Borings have been made at the dam site, at the head-gates, in the deep cuts along the canal line, and at places where masonry structures are to be built at the creek crossings to determine the nature of the material and the presence of water. Test pits and auger holes have been put down at frequent intervals along the canal line and the nature of the material in the canal section has been ascertained.



VIEW AT LOWER YELLOWSTONE DAM SITE, FORT BUFORD PROJECT, MONTANA.

Borings at Yellowstone River dam site, Fort Buford project, 1904.

Hole No.	Distance from base line.	Total depth.	Surface elevation.	Bottom elevation.
	Feet.	*Feet.*	*Feet.*	*Feet.*
A 1	712	21.0	1,978.2	1,957.2
A 8	163	16.5	1,972.2	1,955.7
A 10	92	22.0	1,976.6	1,954.6
A 11	322	19.0	1,972.6	1,953.6
A 12	456	19.0	1,974.6	1,955.6
A 13	650	19.0	1,969.5	1,950.5
A 23	732	26.0	1,985.4	1,959.4
A 26	15	30.0	1,983.2	1,953.2
B 2	710	20.0	1,977.2	1,957.2
B 9	104	18.0	1,974.8	1,956.8
B 14	660	19.5	1,969.0	1,949.5
B 15	520	27.3	1,973.3	1,946.0
B 16	358	21.5	1,972.9	1,951.4
B 17	232	20.8	1,971.2	1,950.4
C 3	718	20.8	1,977.2	1,956.4
C 18	106	22.0	1,977.0	1,955.0
C 19	296	21.2	1,971.7	1,950.5
C 20	430	23.3	1,974.0	1,950.7
C 21	545	47.2	1,972.7	1,925.5
C 22	648	23.0	1,969.4	1,946.4
D 4	688	18.7	1,976.3	1,957.6
E 5	689	20.5	1,977.3	1,956.8
F 6	700	20.0	1,977.3	1,957.3
G 7	712	20.0	1,976.2	1,956.2

Hole A1: 0–21 feet hard blue clay.

Hole A8: 0–8.5 feet sand and gravel; 8.5–12.5 feet tough clay; 12.5–15.5 feet lignite; 15.5–16.5 feet tough clay.

Hole A10: 0–17.5 feet sand and gravel; 17.5–22 feet tough blue clay.

Hole A11: 0–10 feet sand and gravel; 10–19 feet tough blue clay and fine sand.

Hole A12: 0–12.5 feet sand and gravel; 12.5–19 feet tough blue clay with some fine sand.

Hole A13: 0–19 feet tough blue clay and fine sand.

Hole A23: 0–3 feet sand, gravel, and loose lignite; 3–6.5 feet lignite; 6.5–26 feet tough clay.

Hole A26: 0–6 feet cobblestones and sand; 6–12 feet fine sand; 12–30 feet tough clay with a little lignite.

Hole B2: 0–1 foot river mud; 1–20 feet hard blue clay.

Hole B9: 0–13.2 feet sand and gravel; 13.2–15.2 feet sandstone; 15.2–18 feet sand and gravel.

Hole B14: 0–1.5 feet tough blue clay; 1.5–3 feet lignite; 3–19.5 feet tough blue clay and fine sand.

Hole B15: 0–4 feet sand and gravel; 4–20.5 feet tough blue clay and fine sand; 20.5–25.5 feet clay and lignite; 25.5–27.3 feet tough blue clay.

Hole B16: 0–8.5 feet sand and cobblestones; 8.5–13.5 feet fine sand; 13.5–19.5 feet tough blue clay and lignite; 19.5–21.5 feet tough blue clay.

Hole B17: 0–11.8 feet sand and gravel; 11.8–20.8 feet tough blue clay.

Hole C3: 0–20.8 feet tough blue clay and fine sand.

Hole C18: 0–9.5 feet sand and gravel; 9.5–18.5 feet tough blue clay; 18.5–22 feet tough clay and lignite.

Hole C19: 0–10.2 feet sand and gravel; 10.2–21.2 feet tough blue clay.

Hole C20: 0–11 feet sand and cobblestones; 11–23.3 feet tough blue clay.

Hole C21: 0–3.2 feet sand and gravel; 3.2–47.2 feet tough blue clay.

Hole C22: 0–6.5 feet sand and gravel; 6.5–23 feet tough blue clay.

Hole D4: 0–18.7 feet tough blue clay and fine sand.

Hole E5: 0–20.5 feet tough blue clay and fine sand.

Hole F6: 0–20 feet tough blue clay and fine sand.

Hole G7: 0–20 feet tough blue clay and fine sand.

SURVEYS.

Where the country is not broken the canal line has been mapped on a scale of 400 feet to 1 inch, with 5-foot contour intervals; where rough and broken a scale of 100 feet has been used, with 2-foot contour intervals. The center line of the canal has been located on the ground, and all land surveys have been connected. At the head-gates and where special structures are to be built at the creek crossings careful detailed surveys have been made on a scale of 50 feet to 1 inch, with 2-foot contour intervals. The high-water marks and slopes of the streams have been determined, as well as availability of all necessary material, such as stone, sand, gravel, and water. Distances from railroads have also been noted. The areas of the watersheds of the different creeks have been obtained in order that the necessary area for the waterway for the creek may be determined for each crossing. Some of these creeks are 40 miles long and carry large volumes of water for short periods.

The irrigable lands have been mapped on a scale of 1,000 feet to an inch, with 5-foot contour intervals, so that the sizes of the main canal and the location of the laterals and pumping plants can be studied in detail. All the land mapped has been classified.

WATER USERS' ASSOCIATION.

A water users' association, under the name of the Lower Yellowstone Water Users' Association, has been formed and a large percentage of the lands subscribed. It is probable that by January 1, 1905, all the land covered by the canal will be subscribed and negotiations entered into between the association and the Secretary of the Interior regarding a contract with the Government to build the necessary works. It is expected that detailed estimates and plans will be worked up for all the structures this winter, so that if all other obstacles are removed the whole work can be advertised next March and construction begun early in the spring.

IRRIGATION BY PUMPING.[a]

Investigations in North Dakota were commenced about the middle of August by H. A. Storrs, electrical and mechanical expert, in order to determine whether it is feasible to irrigate any portion of the State by pumping from the streams in the western part, using lignite as fuel. A hasty reconnaissance was made, the report of Prof. Frank A. Wilder, of the North Dakota Geological Survey, and the maps of the Missouri River Commission were studied, and field work was commenced, P. M. Churchill, engineer, being placed in charge.

A party was organized at Williston, N. Dak., about September 4, which made preliminary surveys on the Buford-Trenton and the Nesson flats. Since the last of September James A. French, assistant engineer, and his party have aided in this work, spending the remainder of the season in field work in the vicinity of Bismarck.

The field work of the past season was devoted chiefly to certain localities on the banks of Missouri River between Fort Buford and Bismarck.

The distance between these two points by river is 300 miles, and the average fall of the river about one foot per mile. Along the banks, especially the left bank, are areas of low flats easily irrigable by pumping from the river. Their elevation above low water ranges from 20 to 35 feet. Back of these are bench lands, ranging from 40 to 200 feet above the river. Owing to the very slight fall of the river, it has thus far not been deemed feasible to divert water from the river and distribute it by gravity onto these flats. Fortunately the local conditions are favorable to the use of steam pumping plants, since large tracts can be supplied by single plants with comparatively low lifts and short canals. The supply of water is abundant, and fuel is cheap and plentiful.

BUFORD-TRENTON PROJECT.

GENERAL DESCRIPTION.

On the north side of Missouri River a series of flats extend from the Montana-North Dakota line to about 4 miles east of Williston, a distance of 28 miles. The larger of these, that at Buford, extends from the State line eastward about 9 miles and covers 18,000 acres, which is the extent of the Buford-Trenton project (Pl. XLIX).

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[a] From report by H. A. Storrs, electrical engineer.

The next flat, that at Trenton, is 5 miles long and contains 4,000 acres. The area of the next flat, that at Williston, is indefinite, as it depends upon the height to which it is deemed advisable to raise the water. It may be roughly taken at 7,000 acres. Of these, the Buford-Trenton flat is the most important.

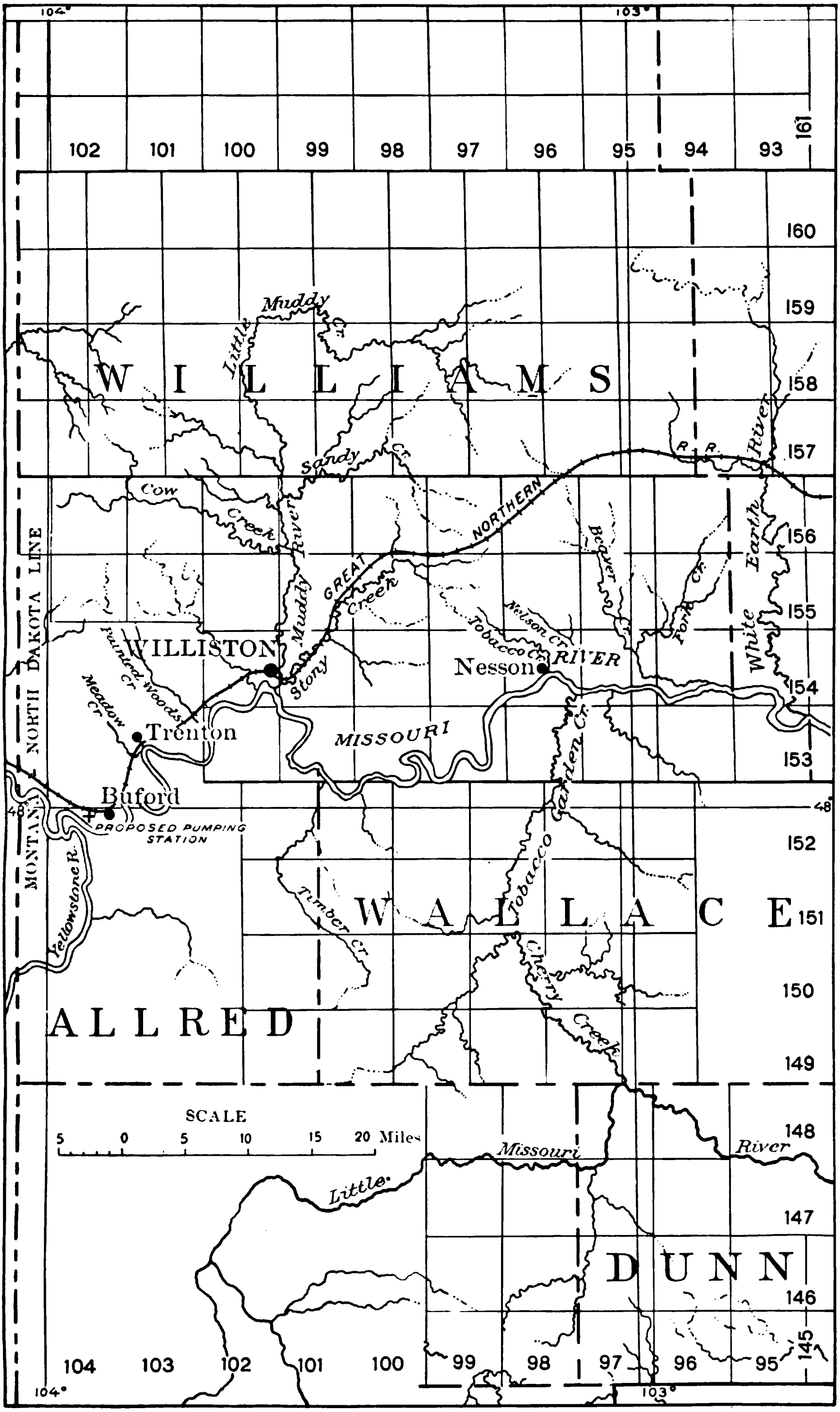
From the river these flats extend northward from 2 to 4 miles, where they meet the hills, at the base of which runs the Great Northern Railway. These hills contain lignite coal, in veins from 2½ to 4 feet thick. Several small creeks run onto the flats from the hills, and it is claimed by the residents that they will furnish water enough, if properly dammed, to supply the first irrigation.

OPERATIONS.

It was found that the Missouri River Commission maps covered most of this territory, on a scale of 1,000 feet to 1 inch, with 20-foot contours. A stadia transit line was run along the base of the hills in order to determine the approximate area and location of the land that can be reached and the approximate location of the canal lines. At the proposed location of the power plant and headworks enough work was done to furnish a map sufficiently accurate for making a preliminary estimate of the cost of the plant. While the surveying party was at Buford a gage was established in Missouri River. This was read once a day, the readings obtained nearly covering the extreme low-water period. One rough discharge measurement was also made. Data on the coal supply, nature of the soil, cost of material, etc., have also been obtained.

OUTLINE OF PROJECT.

It is proposed to dam the creeks or coulees and store as much of their spring floods as possible, this water to be used for the first irrigation and to be distributed by gravity. The main supply, however, will be furnished by pumping. About 1½ miles west of Buford railway station it is proposed to locate a pumping plant. Water will be here pumped through an open intake from the Missouri River and delivered through pressure pipes to canals at three different elevations above low water in the river, viz, 25, 60, and 80 feet. Nearly two-thirds of the Buford flat can be reached by a 25-foot lift; of the remainder, the 60-foot lift will cover about four-fifths and the 80-foot lift one-fifth. The high-line canal will also cover the flat east of Trenton, and if carried on would cover nearly all of the Williston flat. It may prove possible to irrigate much of the Williston land by gravity from Little Muddy Creek, which runs through it. The creek is now being gaged, and this, together with the surveys now being made, will enable this point to be determined.



GENERAL MAP OF PROPOSED BUFORD-TRENTON PROJECT, NORTH DAKOTA.

NESSON RECONNAISSANCE.

GENERAL DESCRIPTION.

Nesson is on the banks of the Missouri, about 25 miles east of Williston. Two flats start here and extend downstream, the lower one for about 18 miles, the upper for about 6 miles, with an area of 10,000 acres in each. The lower flat can be reached by a lift of 30 feet, while the upper requires a lift of about 120 feet. The soil on the edge of the upper is thin and is underlain with sand and gravel. On the western edge of this area lies Tobacco Creek, which extends northward for about 6 miles. This creek near its mouth will make a very good reservoir site. Its banks also contain an 8-foot vein of coal.

Two other creeks, Nelson and Beaver, discharge through, or onto, the land covered by this project. The former is now largely appropriated by Mr. Nelson to give his farm of 1,000 acres one irrigation a year. Beaver Creek, the largest of the three, lies east of the upper flat and flows the year round.

OPERATIONS.

Early in September a reconnaissance of the locality was made, and a survey party was sent to it a few days later. As the Missouri River Commission maps covered only the lower flat and the edge of the upper flat, it was necessary to run a stadia transit line around the outer edge of the latter to obtain its area. An approximate survey was made of Tobacco Creek and vicinity to aid in designing the pumping plant, and a large hill on the upper flat was also outlined. A temporary gage was erected in Missouri River, which has been read once a day and extreme low water obtained. A permanent gage has also been erected.

OUTLINE OF PROJECT.

It is planned to dam the mouth of Tobacco Creek and raise water from the Missouri River to the reservoir thus formed, with a lift of 30 feet. The low-line canal will run by gravity from this reservoir and will cover the entire low flat.

For the high flat the water may be run north in the reservoir about one-half mile where the bluffs on the sides of the creek narrow to about 700 feet. Another dam may be placed here and a lift of 90 feet made from the lower to the higher reservoir. Water may then be raised from this higher reservoir to a high-line canal. It is expected that this high reservoir will hold most of the flood waters of this creek, and that a large part of the supply for the upper flat will be thus obtained.

Nelson and Beaver creeks can also be dammed and water from them used to a large extent by gravity. It may be necessary to pump for a little high land from Beaver Creek, but this is not yet determined. By properly storing the waters of this creek and using them in connection with those of the other two creeks, it is believed that much less pumping from the Missouri for the high flat will be required. Coal exists on Beaver Creek in good quantities.

BISMARCK PROJECT.

GENERAL DESCRIPTION.

A series of flats covering 20,000 acres of land commences near the bridge of the Northern Pacific Railway just west of Bismarck and extends southward along the east side of the Missouri to the vicinity of Glenco. By lifting water from the Missouri 25 feet at the railway bridge and delivering it to a canal running around the upper or eastern part of these flats, this whole area may be covered. The Missouri River Commission maps covered all but a small portion of this area.

Above this lie another series of flats. These are somewhat rolling and their extent is indefinite, depending largely upon the lift to which it is economical to pump. A survey now being made indicates that a lift of 150 feet above low water in the river will cover all of the area, including Bismarck, N. Dak., from near the railway bridge, east up Apple Creek, including Dawson and Tappen on the Northern Pacific Railway, and extending south an indefinite distance.

Southeast of Apple Creek lies a high divide. The Soo Line Railway runs through a low pass in this divide at Magnus. Surveys so far made indicate that an 80-foot lift will cover most of the flat at Bismarck, will pass through this divide at Magnus, and will cover a large tract farther south, the area of which has not yet been determined. This same lift will carry water up Apple Creek to McKenzie on the Northern Pacific Railway, where there is a large, low meadow called McKenzie Slough. This meadow may be connected with Long Lake by cutting a canal through a short divide. It is possible that water may be run by gravity from here onto large flats south of Dawson. A lift of perhaps 75 feet more at Dawson would cover a large flat in that vicinity. Investigations have not yet been carried far enough to say how much land may be reached by these means.

OPERATIONS.

In September a plane-table party under James A. French began work at Bismarck. A plane-table traverse line was run with enough contours and side shots to give an idea of the size and shape of the upper bench and something of its elevation. This line was extended through the pass at Magnus, around the hill to the south, and onto the flats south of Stewartsdale.

OUTLINE OF PROJECT.

Pending future investigations to determine the full extent of the complete project, a tentative plan has been worked out in some detail to show the feasibility of a project covering the flats extending south and east from Bismarck to Apple Creek. It is proposed to place a pumping plant about three-quarters of a mile below the Northern Pacific Railway bridge at Bismarck and there lift water for 15,000 acres into a main canal 25 feet above the river. This canal will follow the top contour of the first bench or bottoms, and from it water can be distributed over about 7,000 acres of bottom lands. At a point on this main canal about 2 miles below the main pumping plant an auxiliary pumping plant will take out water for the next higher bench. The pumping lift here will be 25 feet for 7,000 acres and 25 feet for an additional 1,000 acres.

Should further investigations lead to an adoption of a project extending beyond the limits of the present plan and estimate, it is probable that a central power plant could be located close to the coal supply, from which power could be transmitted electrically to the pumping plants. These pumping plants would be widely scattered over a large area in case the larger project should be adopted, and transportation of coal to steam plants so scattered would probably be more expensive than transmission of electric power. Moreover, the cost of operation of numerous small steam plants would be more than for the same number of electrical pumping plants.

CHERRY CREEK RECONNAISSANCE.

Directly south of Nesson, extending southwestward from the Missouri to the Little Missouri, is a valley through which at one time the Little Missouri may have run. It is now occupied by four small creeks, viz, Tobacco Garden Creek, which runs about half way down the valley and flows north into the Missouri; Cherry Creek, which rises near the Little Missouri, flows northeast nearly to Tobacco Garden Creek and then turns southeast to the Little Missouri; Red Wing Creek, which heads near Cherry Creek and flows southeast into the Little Missouri; and Bolan Creek, which rises near Red Wing Creek and flows southwest into the Little Missouri. None of these creeks carry very much water and the divides between them are not perceptible to the eye. A hurried trip up this valley indicated that it has a general slope from the Little Missouri to the Missouri. A lift of about 200 feet from low water in the Little Missouri will be required to reach this land, after which the water can be distributed by gravity. As the Little Missouri has practically no low-water flow, it will be necessary to dam it and store its flood waters. It may be possible in this manner to reduce the lift to 100 feet. Approximately 40,000 acres of irrigable land may be thus reached. Coal is visible in the banks the entire length of the valley and the land is nearly all in Government ownership.

The project is worthy of further investigation, and it is recommended that a thorough reconnaissance be made in that locality next spring, to be followed by such surveys as the results of the reconnaissance indicate are necessary.

WASHBURN RECONNAISSANCE.

From a trip made from Washburn to Coal Harbor it appears that a tract of lowland of several thousand acres extent exists between those points. This may possibly be reached by a lift of from 150 to 200 feet at Washburn. Coal is available near by. A thorough reconnaissance will be made of this area.

DES LACS RECONNAISSANCE.

A trip made from Berthold on the Great Northern Railway to Donnybrook and Des Lacs River and then up the river to Kenmare indicated that a strip of very level land, perhaps 10 miles wide and at least 50 miles long, could be reached by a 200-foot lift at Kenmare. Coal is plentiful, but it is doubtful if the supply of water is sufficient to warrant any further work at present. The river is being gaged at Foxholm, and at least two years' complete records should be obtained before anything more than a reconnaissance is attempted. Des Lacs Lake is 30 miles long, a half mile wide, and is said to be from 10 to 40 feet deep.

MOUSE RIVER RECONNAISSANCE.[a]

Mouse River heads in Canada and flows southeastward into North Dakota for 150 miles, where its course is southerly for about 90 miles to Minot. Beyond Minot it flows eastward for 30 miles; it then gradually winds its way to the north, and recrosses the Canadian line about 45 miles east of the point where it enters the State. Its general direction is then toward Hudson Bay. In North Dakota it incloses a strip of land locally known as the "loop," which contains approximately 1,600,000 acres. The highest land in the loop lies along the river on its southerly course, where the river is confined to a low flat valley from 100 to 200 feet deep. This high land slopes gently toward the east, its drainage being into the river as it flows northward into Canada. At a point about 4 miles east of Minot is the lowest depression through this watershed, known as the Surry divide.

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[a] From report by James A. French.

The results of a barometric reconnaissance indicate that by the construction of a diverting dam at Overholt, about 35 miles above Minot, water could be held back and raised sufficiently to enable the building of a canal to carry it over the Surry divide to Buffalo Lodge Lake, where it could be stored and eventually used in irrigating much of the land to the north and east.

The discharge of Mouse River is very irregular, there being a succession of periods of drought and occasionally a destructive flood. During the spring the flow is usually large and in April and May, 1904, the mean discharge at Minot was 3,200 second-feet. The greatest flood on record for over twenty years occurred during these months. Later in the season the quantity of the flow declines and in July and August drops to about 200 second-feet, or even less. In years of small rainfall the bed of the river frequently becomes dry. It is evident from a study of the facts that storage of the flood water is necessary if irrigation is to be systematically practiced. The land available for storage is, however, valuable farm land in the valley, and a considerable area of this would be destroyed in order to save water for use on other lands of not much greater value. Storage in the river valley is also limited by the fact that a dam of any considerable height will back water into and flood lands in Canada.

If a dam should be built creating a reservoir in the valley above Minot it would be necessary to provide a very large flood canal to relieve the flow and convey the water quickly through the Surry divide to Buffalo Lodge Lake.

The point considered for a diverting dam was 2 miles south of Overholt, where the hills close in on either side of the river and are approximately half a mile apart. The height of the dam is limited to approximately 30 feet; a higher dam would back water into Canada. This would lift the water 20 feet and allow a depth of 10 feet in the canal. The dam could be constructed of earth with a masonry core wall of concrete.

The canal at this elevation of 20 feet above the river would follow an excellent location for construction, as there is only one large and a few small drainage lines to be crossed. As the line approaches the Surry divide the cut increases rapidly, and for over 2 miles would be in approximately a 40-foot excavation. After passing through the divide the natural drainage would carry the water to the depressions in the vicinity of Buffalo Lodge Lake.

The system for distributing water from Buffalo Lodge Lake would not be expensive, as the lands to be covered are gently undulating, and by careful study the water can be carried widely over the country. There are, however, a number of isolated depressions, and it would be necessary to construct a drainage system in order to prevent the formation of marshes on some of the good land.

A line of levels starting at the Surry divide was carried along the line of approximate canal location to the dam site. The elevation of the divide is 1,610 feet, while the elevation of river bottom at dam site is 1,590 feet. A traverse line with transit following the proposed canal was carried from the east end of the dam along the bottom lands to the Surry divide. The line, when platted with the necessary curves, has a length of 39.75 miles to the point where it enters the Surry cut. Then for 5 miles the line crosses the divide in a deep cut. At the west end the ground rises rapidly until the cut reaches its maximum of 40 feet. For 2½ miles the cut would be approximately 40 feet deep, gradually decreasing in depth until the canal line enters the slough draining to Buffalo Lodge Lake. By means of these traverse lines an estimate of the amount of earth to be removed was made. Beyond the Surry divide no surveys were made of the storage possibilities or of the irrigable area. The excessive cost of constructing a long diversion dam, a canal 40 miles in length, and a heavy cut of over 3 miles through the divide led to the conclusion that further investigation was not warranted.

At the time the surveys were completed the possibilities of pumping water from the river were considered in part. From the results of the surveys it appears that the feasibility of pumping water from the river below Minot, across the Surry divide, might be considered. The required lift is less than 60 feet, and the water would then flow down the drainage to Buffalo Lodge Lake, where it could be stored for use in irrigation.

The river could not be dammed at a point below Minot, but sufficient water could be taken out of the river during the spring flood and even in the summer. There may also be a possibility of pumping water at the dam site near Overholt. The lift would be approximately 150 feet. A dam 30 feet high at this point would give fair storage capacity. This water could be used immediately to the east, toward Lansford and the Deep River drainage. There is plenty of land, and the acreage to be irrigated is limited only by the amount of water available. Lignite coal occurs in abundance along the river, but is all in private ownership.

The surveys show that it is not practicable nor feasible to divert water by gravity alone in this vicinity on a basis that would be commercially profitable. A large canal, depending on the regular flow of water during the irrigating period, would be dry when the water is most needed. The solution of this problem may be found in direct pumping or in a combination of pumping and gravity. The lands which might be benefited by any such pumping and gravity supply are practically all in private ownership and are in the natural condition highly productive, excepting in times of drought. The average area owned by an individual is usually in excess of 160 acres. The present owners are not experienced in irrigation, and, while they would like a supply of water in times of drought, are, as a rule, not willing at present to commit themselves to the payment of the cost of irrigation or to intensive farming. This is notably the case during such a year as 1904, when the precipitation was heavy and some of the land was more in need of drainage than of irrigation.

It is probable, however, that when the seasons of drought come on there will be an urgent demand for water, and if it could be had at reasonable cost at such times the landowners would then be willing to pay for it.

LITTLE MISSOURI RIVER RECONNAISSANCE.[a]

Little Missouri River heads in Wyoming and flows northeastward across the southeast corner of Montana and the northwest corner of South Dakota. In North Dakota it flows northward for 100 miles, and then finally turns abruptly eastward and empties into Missouri River in the Fort Berthold Indian Reservation. Through South Dakota for 30 miles the river flows in a flat, rolling country, the hills on either side being distant from 1 to 5 miles. The banks along the river are from 10 to 30 feet above the river bed. As the stream continues to the north the hills gradually approach closer to the river. The tributaries also increase in size proceeding downstream; so at the Badlands the "cut banks" are several hundred feet in height and the side ravines have lengths of 20 miles or more.

A barometric reconnaissance was made in this vicinity in the spring of 1904 by S. B. Robbins, engineer. From his report it was concluded an instrumental survey was needed to determine the possibility of diverting the river in the vicinity of Ashcroft, S. Dak., and leading its waters across one of several divides into the drainage of the Cannonball or Grand River.

The water in Little Missouri River, especially during the spring floods, comes from the melting snows in Wyoming and Montana. During a few weeks in the spring a flow of several thousand second-feet may be expected. The amount varies considerably, and while the flood flow during the spring may be as low as 100 second-feet for a number of days, at other times of the year the supply from rains may be larger. A good water supply may be had nearly every spring and a fair quantity occasionally during the summer months. For example, at Medora, N. Dak., 80 miles below the proposed point of diversion, there was in July, 1903, a mean flow of 1,083 second-feet; in July, 1904, the flow was 120 second-feet; in August, 1903, 2,295 second-feet; in August, 1904, 10 second-feet; in May, 1903, 952 second-feet; in May, 1904, 200 second-feet.

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[a] From report by James A. French.

These two years, 1903 and 1904, according to the oldest inhabitants, were more humid than usual. A careful study of the available amount of water is of particular importance where, as in this case, an exceptionally long line of canal is required to divert the water to the irrigable lands.

The small discharge that usually occurs during the period when water is required for the crops—namely, in June, July, and August—necessitates the storage of water at some point. There are no available reservoir sites along the river in its course through Montana and South Dakota, the country being flat and open. Storage, if any, must be provided along the canal at some point beyond the divide leading into the Cannonball and Grand River drainage.

The point selected for possible diversion was 20 miles south of the south boundary line of North Dakota and 4 miles north of Ashcroft, S. Dak. Here the valley narrows so that it is possible to divert the water by a low dam, 250 feet in length, raising the water approximately 15 feet above the bed of the river. The flooded area above this dam would be small, and the land is of little value. A diversion could be made at the grade of the river bed itself, but it would be better to divert as high as possible in order to get away from the river and also to lessen the cut at the divide into Grand River.

The proposed canal line runs for 15 miles through country that is fairly good for construction, except at three or four places, where cut banks along the river would be encountered. In the vicinity of the State line between North Dakota and South Dakota the canal line must go around the head of several creeks which can not be crossed by means of an ordinary heavy fill. Farther down the river the creeks entering from the east are longer, the canyons deeper and wider, and the side hills and cut banks of great height. It would be almost impossible to cross Spring, Skull, Coyote, Seven, Five, Horse, and other adjacent creeks by ordinary flumes, siphons, or by fills, owing to the great expense.

To carry a canal around the head of these creeks would require 10 miles or more of heavy work in each case, with numerous culverts and large fills. Where these creeks cross the line of the canal they vary from 50 to 200 feet in depth and from 1,000 to 4,000 feet in width. On or near each creek is a cut bank from 50 to 100 feet in height and cliffs from 400 to 1,000 feet or more in length. It is impossible to avoid crossing these. Below Spring Creek the river is in the Badlands, and inspection shows that canal construction is impracticable.

At Bacon Creek the proposed canal turns east and leaves the Little Missouri. By a tunnel at the head of Bacon Creek the canal can be carried into the Deep Creek drainage. Deep Creek drains into the Little Missouri at a point about 50 miles below Bacon Creek. After passing through the tunnel, which would be about 5,000 feet in length, the line runs almost due east, with the exception of windings as it passes about the heads of the numerous forks of Deep Creek. The country here is considered to be heavy work for construction. The valleys along the creeks are narrow, and the benches have a considerable slope up to the clusters of small buttes that cover three-fourths of the area in this vicinity.

This section of the line from the Bacon Creek tunnel to the Cedar Creek and North Fork of Grand River divide would not encounter any heavy cuts or fills, but it would be on a side hill all the way. The length of canal line to Cedar Creek divide by way of Bacon Creek tunnel is 70 miles. To avoid the tunnel at the head of Bacon Creek and follow the contour around into Deep Creek would add 100 miles to the length of canal, making the total length 270 miles, nearly all of which would be in the Badlands, and bring the location of the line back to the east end of the tunnel, with a corresponding loss in elevation.

The tunnel being through a soil that is readily affected by water, would have to be protected by masonry lining throughout.

Along the line of canal, beyond the Cedar Creek divide, are several small reservoir sites that are available for storage. The possible extent of storage was not fully examined, as this did not seem necessary after finding the great length that water must be carried to reach a storage place. From observations made in traveling over the country and from reports of S. B. Robbins, engineer, and E. F. Chandler, State engineer, it is evident that there is ample land for irrigation purposes along the Grand and Cannonball rivers, but no surveys or estimates were made of this area.

By making an extension, or 20-mile branch of the canal before it crosses Cedar Creek divide, water could be carried over Sand Creek divide into Sullivan Creek, which drains into Cannonball River. The first half of this line would be in good ground for construction, but the latter half, through Sand Creek drainage, is very rough.

No reliable estimate of cost can be made from this reconnaissance, as it consists simply of a line of levels run to determine the elevations of the several divides and the approximate length of line necessary. A number of side lines of levels were run from the main line to determine the elevations of divides into Spring Creek and at other points where it was thought it might be possible to get through and shorten the length of the main line. All of these divides were found to be too high to be crossed by gravity and too long to be pierced by tunnel, none being less than 6 miles in length.

No place was found along Little Missouri River where it is possible to construct a dam to store the waters. There is no dam site and no reservoir capacity, the river falling approximately 8 feet in 1 mile, and with a narrow valley leaving a small area for storage.

A more detailed investigation of the possibility of diverting the Little Missouri River in this vicinity would only involve unnecessary expense. A drive along the line that must be followed shows at a glance the enormous amount and prohibitory cost of the work that must be done, particularly along the river in North Dakota. The expense of any diversion of water from Little Missouri River eastward would be far too great to be repaid by the possible benefits.

OPERATIONS IN OKLAHOMA.

By Gerard H. Matthes.

It is evident from the many letters and requests for information that irrigation works in the arid and semiarid portions of Oklahoma are greatly desired. Efforts have been made to look into all proposed irrigation schemes which seemed to warrant the time. Reconnaissance surveys of this kind have been made during the year in Beaver and Washita counties by L. M. Holt, assistant engineer. The following statements are from his report giving the results of his surveys:

CIMARRON RIVER.

STORAGE NEAR KENTON, BEAVER COUNTY.

During the latter part of March, 1904, a plane-table survey was made of a reservoir site in sec. 33, T. 6 N., R. 1 E. of the Cimarron meridian, on Cimarron River, 2½ miles northeast of Kenton. At this point the wall of the canyon on the south side of the river projects toward the river. At the dam site the canyon has steep side slopes and a width of 2,330 feet at the 100-foot contour. The reservoir site lies west of this point. The survey was on the scale of 1,000 feet to 1 inch, with contour intervals of 10 feet, the zero point of the survey being the bed of the river at the dam site. The land within the basin is in private ownership; about 20 per cent of the bottom lands are in alfalfa; the remainder is practically uncultivated.

The area of the reservoir as obtained from the map is shown in the following table:

Capacity of Cimarron River reservoir site at different contours.

Contour.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*
20	155	1,454
40	800	10,990
60	1,315	32,130
80	2,550	70,770
100	4,500	141,270

The drainage area of Cimarron River at this point is 850 square miles. No record of its discharge has been kept, but at the time of the survey only 1½ second-feet were flowing in it. Since that time a gage has been established near Kenton. The residents in the vicinity of Kenton state that large floods come down the river and for hours at a time the stream is one-half mile wide and deep enough for a horse to swim. Owing to the fact that only isolated discharge measurements have so far been made the run-off can not be accurately determined, but by comparing the drainage area with that of similar streams in the same section of the country the run-off is estimated at 30,700 acre-feet per annum, sufficient to fill the reservoir to the 60-foot contour. A rubble masonry dam storing water to this height was figured on. The depth to bed rock, which is red sandstone, is 30 feet. The crest of the dam would have a length of 2,150 feet and a height above bed rock of 90 feet. The walls of the canyon are steep and composed of red sandstone.

A spillway could be cheaply built around the north end of the dam by quarrying the stone for the construction of the dam at that point. A canal from the reservoir to irrigable land would be 30 miles in length, as the valley is narrow and contains only narrow strips on each side of the river. The cost per acre-foot of storage, not including the 30 miles of canal, would be $52.90.

The cross section of a dam site 5 miles east of Kenton was also mapped. This was thought by the people of the vicinity to be a better site than the one near Kenton, but was found to be several hundred feet wider. The reservoir would be narrower, but would be deeper and approximately of the same capacity. It would have a larger drainage area, as Carriso Creek empties into the Cimarron River above this point. The cost of this project is excessive and renders it impracticable.

STORAGE NEAR COIN, BEAVER COUNTY, OKLA.

A plane-table survey was made of a dam and reservoir site 6 miles east of Coin, on Cimarron River, the dam site being in sec. 32, T. 6 N., R. 28 W., of the Cimarron meridian. The dam site is very wide, measuring 5,400 feet between the 35-foot contours. On the south side of the river is a vertical clay bank 32 feet high, while on the north side is a gently sloping hill. The underlying strata are 10 feet of river sand, then 10 feet of clay, and, overlying the bed rock, which is red sandstone, another stratum of sand 10 feet in thickness. These strata extend some distance beneath the soil on the south side of the dam site, and the same formation is found in wells one-half mile distant. It was suggested by Colonel Perry, of Englewood, Kans., that an earth dam with a concrete core be constructed down to the stratum of clay. As the strata extend beneath the south bank, a water-tight reservoir of any kind could not be constructed, except at inordinate expense. The reservoir, if constructed, would have a storage capacity of 27,000 acre-feet. The discharge of Cimarron River at the time of the survey was 84 second-feet.

STORAGE AT NYE, BEAVER COUNTY, OKLA.

This dam site is on Cimarron River in sec. 15, T. 6 N., R. 25 E., Cimarron meridian. It was surveyed at the suggestion of Dr. A. J. Sands, chairman of the committee on irrigation for Beaver County, his plan being to dam the river at this point and convey the water in a canal to T. 5 N., R. 26 E., irrigating the flat at that point and filling a natural basin in sec. 18, T. 5 N., R. 27 E., which would irrigate the land below. The north side of the dam site is a vertical clay bank 33 feet high, and the south bank is a range of sandhills unsuitable for a dam. The fall of the river is 7 feet to the mile. The basin on the south side of the river, forming part of the proposed reservoir, is covered with sandhills. The capacity of the reservoir with a 30-foot dam would be 10,000 acre-feet. The land on the south side of the river is 140 feet above the bed of the river and rises to form the divide between Cimarron and Beaver rivers. It is much too high for irrigation. The flat and natural basin mentioned could not be irrigated with water from the proposed reservoir, and the canal would have to follow the canyon for 15 miles before it could be diverted onto the higher lands to the south, and for several miles would have to be constructed through irregular sandhills. The strata at this point are very similar to those at the dam site near Coin, above described, and render the construction of a water-tight reservoir impracticable.

DEVELOPMENTS NEAR ENGLEWOOD, CLARK COUNTY, KANS.

The principal irrigation development along Cimarron River near Englewood, Kans., is that of Col. C. D. Perry, a description of which will be found in the First Annual Report of the Reclamation Service, page 271. The main ditch and two laterals that carry the water from Cimarron River in Oklahoma across the State line to Colonel Perry's ranch were gaged March 30, when the flow in the main ditch was found to be 10 second-feet, and that in the laterals 5 and 6 second-feet respectively. Colonel Perry has a water right of 14 second-feet and states that frequently during the late summer months the river does not furnish enough water for his ditches. He suggested that a reconnaissance survey be made of a reservoir and dam site on Cimarron River about 6 miles east of Coin.

Near the head-gate of Colonel Perry's ditch, on the opposite side of the river, is a head-gate and canal which is owned by another company, and which can only be used when the river carries more water than is needed by Colonel Perry.

CARRISO CREEK.

A trip was made up Carriso Creek, which empties into Cimarron River just below the Kenton dam site, but no suitable location for a dam or reservoir was found on this creek south of the Colorado State line. The flow of the stream was too small to be measured with the current meter and was estimated to be 0.2 second-feet.

EAST ELK CREEK.

STORAGE NEAR SALEM, WASHITA COUNTY.

The East Elk Creek dam and reservoir site are situated on East Elk Creek in T. 9 N., R. 18 W., of the Indian meridian. The flow of the creek at this point was, at the time of the survey, 4 second-feet. The stream is subject to high floods, during which water is 14 feet above the low-water stage and the stream is 200 feet wide. The stream at this point has a fall of 25 feet to the mile, thereby making the storage capacity of the reservoir too limited. On the west side of the creek the dam site consists of a vertical bluff 43 feet high, composed of red sandstone, which in places disintegrates on exposure to the atmosphere; the other bank is a gently sloping clay hill. The total length of the crest of the dam at the 40-foot contour would be 1,100 feet. Bed rock is found at a depth of 1 foot. In order to afford sufficient spillway, it is proposed to construct a rubble masonry dam, with a concrete core, 42 feet in height and 200 feet in length, the remaining 900 feet to be of earth, with a concrete core.

The capacity of this reservoir to the 40-foot contour is 2,000 acre-feet. Only a short canal would be necessary to reach irrigable land. The cost per acre of land irrigated would be $53.80, based on a duty of 1 acre-foot per acre.

BOGGY CREEK.

STORAGE NEAR BESSIE, WASHITA COUNTY.

W. S. Petty, of Bessie, proposed the construction of a dam and reservoir on a branch of Boggy Creek, in sec. 31, T. 11 N., R. 17 W., of the Indian meridian. This creek was reported as being dry during the summer of 1896, but at the time of the survey flowed 2.1 second-feet. At high water, judging from the drift, the stream was 7 feet higher than at low water, and 100 feet wide. The depth to bed rock could not be ascertained. The total length of the crest of a dam would be 2,400 feet. The style of dam proposed is an earth dam, with concrete core about 2,300 feet long and 50 feet high, and an overflow 100 feet long, of rubble masonry. The amount of water so stored would be 4,500 acre-feet. The cost of the dam could not be accurately figured, as the depth to bed rock was not determined. The cost per acre-foot stored would be about $32.50.

WELLS.

BEAVER COUNTY.

A number of wells were visited in the course of the reconnaissance. The well at Guyman is 200 feet deep. The first water horizon was struck at 90 feet and furnished but a small supply; the second horizon was struck at a depth of 174 feet. This well supplies a town of 450 inhabitants and all the people in the country for several miles around. It is 2½ miles from Beaver River. The depths of wells range from 12 feet in the valley to 200 feet at Guyman.

Wells near Kenton range in depth from 30 feet on the flat by the river to 55 feet at Kenton. It was stated by the residents of Kenton that a 6-foot windmill running continuously was unable to exhaust the supply of water from one of these wells.

Wells along the river near the dam site, 6 miles east of Coin, range from 58 to 66 feet in depth. A well in the SW. ¼ sec. 32, T. 6 N., R. 28 E., of the Cimarron meridian is 66 feet deep and extends to bed rock. The log of this well shows 36 feet of clay and sandy loam, 10 feet of sand, 10 feet of hard clay, and 10 feet of sand lying on bed rock. Water is pumped from this well into a small reservoir; the pump has a 6-inch cylinder and is run by a 12-foot windmill. One acre of garden and orchard is irrigated from this well. Half a mile southeast of the latter is a well 58 feet deep through similar strata; a 10-foot windmill with a 5-inch pump raises the water to a reservoir storing 0.6 acre-foot, which irrigates 2 acres of orchard and garden. A well on Doctor Sands's claim near Zelma is 160 feet deep and supplies water for all the stock in the neighborhood. The main trouble with windmill irrigation in this section seems to be due to the small storage capacity of the reservoirs and the lack of sufficient power to raise the water.

WASHITA COUNTY.

Very little irrigation from wells is practiced in Washita County, but the people near Seger, Okla., are greatly interested in deep wells, and feel confident that artesian water can be found at depths of 500 or 600 feet. Levi Shively, a well driller at Seger, states that at a depth of 10 feet below the surface soil is a stratum of red soapstone 150 to 200 feet thick underlain by a porous sandstone, which becomes softer and more porous as the depth increases. The depth of the wells averages 175 feet, ranging from 130 to 300 feet; the water is found in the sandstone and rises to within 40 to 15 feet of the surface of the ground; continuous pumping by windmill does not affect the supply. Mr. Shively adds that in his opinion the wells would furnish a 4-inch stream of water throughout the year, and feels certain that artesian water can be obtained at a depth of 500 or 600 feet.

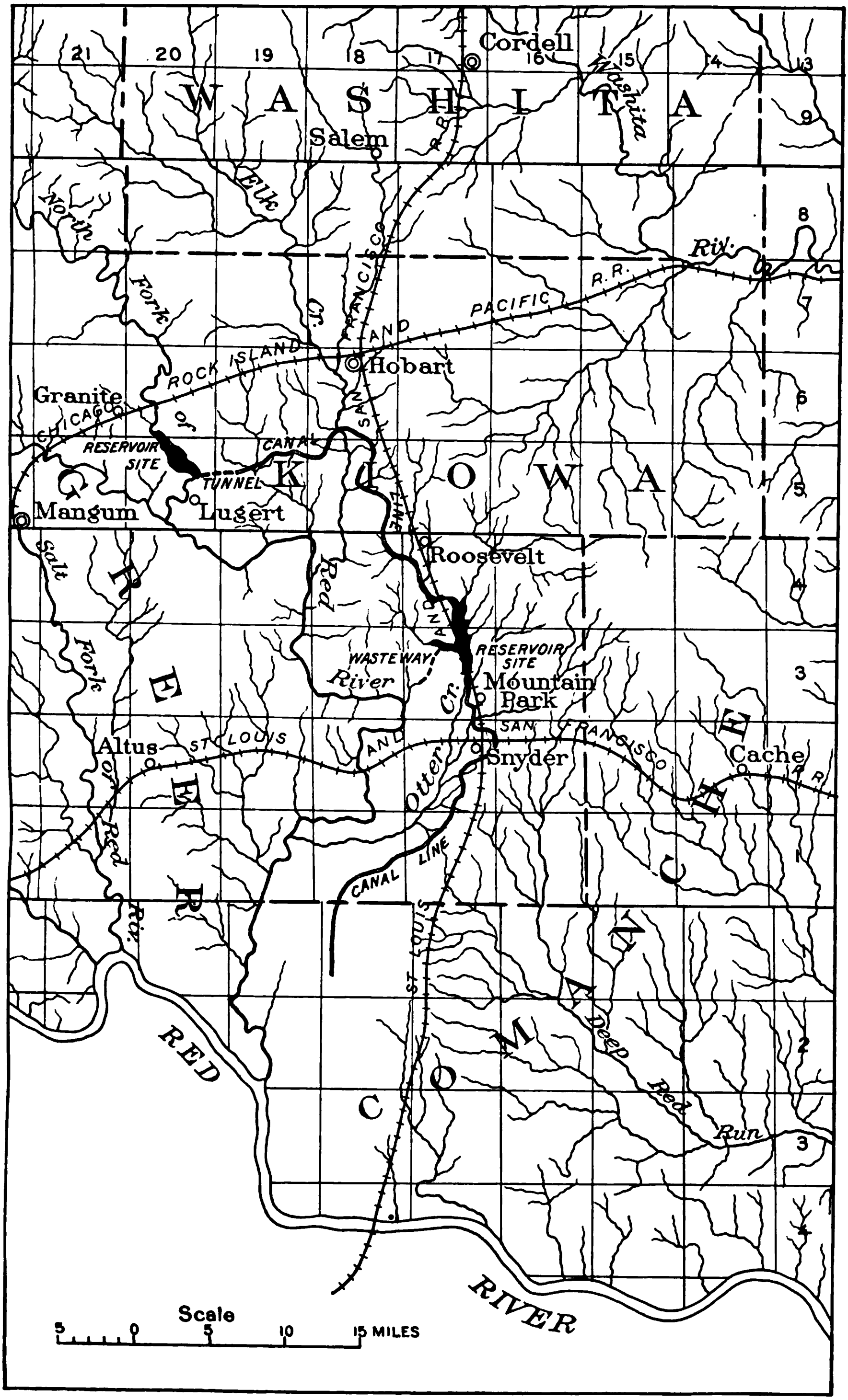
OTTER CREEK PROJECT.

In his report on the results of irrigation surveys made in western Oklahoma during the field season of 1903, published in the Second Annual Report of the Reclamation Service, Ferdinand Bonstedt pointed out that the data relating to water supply secured up to that time were not sufficient for reaching an intelligent conclusion as to the feasibility of the system planned in Kiowa County. Measurements of the flow of North Fork of Red River, Otter Creek, and Elk Creek have been continued up to the present time, and the information concerning the flow of these streams so obtained throws a much-needed light on the situation and renders the formulating of more definite recommendations possible.

Briefly stated, the project as conceived in the original surveys contemplates the construction of a rock-filled dam with a maximum height of 65 feet on North Fork of Red River near Lugert, Okla., and a canal 25 miles in length, including 3 miles of tunnel, to carry the water to another reservoir to be formed by damming Otter Creek near Mountain Park, Okla. (Pl. L). The dam at the latter point is to be of the rock-filled type, 75 feet high in the center, provided with a wasteway for draining the surplus waters into North Fork of Red River. From this reservoir a canal line 27 miles in length has been surveyed, extending through the irrigable lands and terminating in the southwestern portion of Comanche County. The reservoir on Otter Creek may be considered somewhat in the same light as the distributing reservoir of a city waterworks. Its head-gate will control practically all of the water that is to be supplied to the irrigable lands.

WATER SUPPLY.

It is proposed to utilize the Otter Creek reservoir for storing the waters derived from three different sources, namely, the flood waters of North Fork of Red River by means of the reservoir and canal just described; the flow of Otter Creek itself, and a part of the flow of Elk Creek. Elk Creek is crossed by the canal emptying into Otter Creek, and its flow could be diverted into the canal by means of a short canal heading some distance upstream and by suitable training works. No



GENERAL MAP OF PROPOSED OTTER CREEK PROJECT, OKLAHOMA.

opportunity exists for storing the flood waters of the creek, there being no praticable site for a dam and reservoir along its course.

In the accompanying tables are given the results of measurements made on the North Fork of Red River at Granite, Okla., where a gage was established June 23, 1903; on Otter Creek near Mountain Park, Okla., where a gage was established April 20, 1903, and on Elk Creek at a point several miles southwest of Hobart, Okla. A glance at these tables is sufficient to show that the total amount of water discharged by these streams during 1904 was comparatively small. The total flow of North Fork of Red River is estimated at 68,518 acre-feet, or sufficient to fill the proposed reservoir at Lugert, the capacity of which is 66,215 acre-feet, leaving a balance of about 2,300 acre-feet. The total flow of Otter Creek during 1904 is estimated at 4,076 acre-feet, and that of Elk Creek at 11,000 acre-feet, an aggregate of 15,076 acre-feet, a quantity which falls short of filling the Otter Creek reservoir by 66 per cent of its intended capacity of 43,500 acre-feet.

Reverting to the report of Mr. Bonstedt, published in the Second Annual Report of the Reclamation Service, the total yearly supply estimated by him as necessary to fill the two reservoirs, inclusive of losses by evaporation from the reservoir surfaces and by seepage in the reservoirs and main canals, is 135,700 acre-feet. The actual total yearly supply from the sources above mentioned for the year 1904, as it appears in the tables, is 83,872 acre-feet, or about 62 per cent of the amount required. The losses by seepage and evaporation were placed by Mr. Bonstedt at 25,000 acre-feet, or about 18 per cent of the total stored, a very low estimate.

Discharge measurements of Otter Creek at Mountain Park, Okla.

Date.	Hydrographer.	Gage height.	Dis-charge.	Remarks.
1903.		*Feet.*	*Sec. ft.*	
Apr. 20	Ferd. Bonstedt	1.35	7.0	Gage established this date.
May 1	.....do..............	2.20	42.0	
19	L. M. Holt.........	5.70	363.0	Velocity obtained by means of floats.
24	.....do..............	9.90	879.0	Do.
Aug. 13	Holt and Kerby	.95	.7	Measurement made one-half mile below station. No current at station.
Sept. 18	Ferd. Bonstedt	.80	.2	Measured below station by means of floats.
Oct. 22	E. R. Kerby........	.90	.3	
Nov. 26	.....do..............	1.40	2.6	
Dec. 23	.....do..............	1.35	1.6	

Discharge measurements of Otter Creek at Mountain Park, Okla.—Continued.

Date	Hydrographer.	Gage height.	Discharge.	Remarks.
1904.		*Feet.*	*Sec. ft.*	
Apr. 9	L. M. Holt	1.2	1.5	
May 7	E. R. Kerby	1.1	2.5	
27	do	.8	.1	
July 14	do	.9	.1	
Aug. 28	do	.9		Water standing in pools.
Sept. 23	do	.9		Do.
Oct. 22	do	.9		Do.

Estimated monthly discharge of Otter Creek near Mountain Park, Okla.

[Drainage area, 126 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1903.						
April 20–30	179.0	6.0	29.5	644	0.23	0.09
May	457.0	6.0	41.4	2,546	.33	.38
June	4.0	1.8	2.5	149	.02	.02
July	1.8	.8	1.1	68	.009	.01
August	.8	.4	.5	31	.004	.005
September	.8	.2	.4	24	.003	.003
October	1.3	.2	.5	31	.004	.005
November	3.4	1.3	2.4	143	.019	.021
December	2.8	2.3	2.8	172	.022	.025
The period				3,808		
1904.[a]						
January	3.0	2.0	2.50	154	0.020	0.023
February	2.5	2.0	2.07	118	.016	.017
March	2.0	1.5	1.60	98	.013	.015
April	3.0	1.0	1.35	80	.011	.012
May	188.0	.5	8.45	520	.067	.077
June	780.0	.1	40.1	2,386	.318	.355
July	1.8	.1	.40	25	.0032	.0037
August	152.0	0	11.3	695	.090	.104
September	0	0	0	0	0	0
October	0	0	0	0	0	0
The period	780.0	0	5.65	4,076	.045	.607

[a] 1904 monthly estimates are an approximation based on the 1903 rating tables and interpolation between the 1904 measurements.

Elk Creek is a perennial stream fed by numerous small springs and tributaries; it discharges on an average from 15 to 18 second-feet. On account of the regularity of its flow and the fact that its storm waters can not be utilized in any irrigation project, no gage has been maintained on this creek, but occasional measurements have been made, as shown in the accompanying tables. During the late summer of 1904 the severe drought prevailing in that section of the country caused the flow of the creek to diminish appreciably, and on August 29 it had dwindled to only 2.2 second-feet. A gage was erected on Elk Creek on September 22, at a point several miles southwest of Hobart, and regular observations have been made since that date.

The following are the results of the measurements made:

Discharge measurements of Elk Creek near Hobart, Okla.

Date.	Hydrographer.	Gage height.	Discharge.	Remarks.
1903.		*Feet.*	*Sec.-ft.*	
Sept. 18	Ferd. Bonstedt		14.3	
Oct. 22	E. R. Kerby		16.6	
Nov. 26	do		18.0	
Dec. 22	do		17.0	
1904.				
May 6	E. R. Kerby		48.0	
June 9	do		947.0	West Elk Creek, 918 second-feet; East Elk Creek, 48 second-feet.
Aug. 29	do		2.2	
Sept. 22	do	0.9	1.8	Gage established.
Oct. 21	do	.95	3.0	

On June 23, 1903, a gage was established on North Fork of Red River at Granite, where the following measurements have been made:

Discharge measurements of North Fork of Red River at Granite, Okla.

Date.	Hydrographer.	Gage height.	Discharge.	Remarks.
1903.		*Feet.*	*Sec.-ft.*	
June 27	Ferd. Bonstedt	4.8	72.0	Gage established June 23, 1903, on highway bridge 2 miles east and ½ mile north of Granite.
Aug. 12	Holt & Kerby	4.6	61.0	Measured above railroad bridge 200 feet upstream from station. Three channels at station.
Sept. 19	Ferd. Bonstedt	3.7		No flow; water standing in pools. Same conditions continue through October, November, and December.

Discharge measurements of North Fork of Red River at Granite, Okla.—Continued.

Date.	Hydrographer.	Gage height.	Discharge.	Remarks.
1904.		*Feet.*	*Sec.-ft.*	
May 6	E. R. Kerby	4.9	231.0	
26	do	3.5	.1	Velocity by means of floats.
June 9	do	6.2	2,062.0	River running in four channels.
July 13	do	5.1	49.0	
Aug. 30	do			Water standing in pools.
Sept. 22	do			Do.
Oct. 21	do			Do.

Estimated monthly discharge of North Fork of Red River at Granite, Okla.

[Drainage area, 2,210 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1903.						
June 23–30	110	0	23	1,369	0.010	0.003
July	59	0	20	1,230	.009	.010
August 4–15 (gage broken)		0	53	3,259	.024	.028
September	40	0	3	179	.001	.001
October	13	0	1	68	0	0
November	0	0	0	0	0	0
December	0	0	0	0	0	0
The year				6,105		
1904.						
January	0	0	0	0	0	0
February	0	0	0	0	0	0
March	0	0	0	0	0	0
April	0	0	0	0	0	0
May	5,100	0	312	17,371	0.141	0.163
June	4,200	40	651	38,737	.295	.329
July	2,260	0	221	10,964	.100	.115
August	240	0	81	1,446	.037	.041
September	0	0	0	0	0	0
October	0	0	0	0	0	0
Total				68,518		

FEASIBILITY OF OTTER CREEK PROJECT.

In view of the foregoing it is hardly necessary to point out that the Otter Creek project as planned is not feasible. It is doubtless true that the year has been a dry one in that section of Oklahoma, but it can not be asserted that it was one of unusual drought. While the early crops were generally poor, there were no unusual failures of crops, and the cotton produced this year was up to the average. The floods which occurred on the streams mentioned during this year were not as high as usual nor were they of long duration. Neither Otter Creek nor North Fork of Red River showed any perceptible flow from the latter part of August until very late in the year.

In condemning the Otter Creek project as not feasible, it seems fortunate that the considerations which led up to this conclusion were based on the water supply yielded during a fairly dry year, for in this manner the project may be said to have been viewed in its worst aspect. Unquestionably the reservoirs can be filled during an average wet year, but this is a matter of little or no moment, for it is during the dry years that the most water will be needed for irrigation, and it is with these only that the problem is concerned.

It might be practicable to decrease the height of the Otter Creek dam, and consequently reduce the size of the reservoir, thus effecting a saving in total cost, but the cost per acre-foot stored would thereby inevitably be increased and the first expense to the individual farmer become considerably in excess of $13.20 per acre irrigated, as originally estimated.

The estimate published in the Second Annual Report, referred to above, is based on a cost per acre of $15 for land damages. It is doubtful at this time whether the lands situated in the Otter Creek reservoir bottom can be purchased for this price, and it is believed that $20 per acre is probably nearer their average value, increasing the total cost of the project by $20,000.

GENERAL SUMMARY.

The localities visited in Oklahoma Territory by engineers of the Reclamation Service include portions of Beaver, Day, Comanche, Greer, Kiowa, Roger Mills, Washita, Wood, and Woodward counties. A number of proposed projects, located either in part or in whole in the above counties, have been surveyed, but in a majority of instances have been found to be impracticable, either owing to too great a cost involved, or to physical disqualifications, such as lack of suitable foundations, too great a width at the dam site, sandy and unreliable character of the stream, shortage of water, and other drawbacks.

The results of the surveys given in the preceding pages are typical illustrations of the nature of the difficulties encountered.

Generally speaking, in western Oklahoma, so far as known, there are no good opportunities for the storage of flood waters, natural dam sites being lacking. In addition, the water supply, with few exceptions, is unreliable. The great majority of the streams which it is proposed to utilize are dry during four or five months of the year and their freshets are exceedingly variable, both as regards the amount of water they discharge and the frequency with which they occur. The Otter Creek project, including portions of Kiowa and Comanche counties, is the only one deemed worthy of consideration under the provisions of the reclamation law.

At a few points irrigation by the use of windmills and wells has been undertaken, and the results, while necessarily applicable to small areas only, have been satisfactory. The depth to underground water throughout western Oklahoma is variable and uncertain, and this method of irrigating can, therefore, be practiced in certain localities only. Nevertheless, it is not resorted to as widely as would be expected, since in many sections it could be made to afford limited relief at times of drought and be of general utility on the farm at any time.

Many arguments have been presented favoring the utilization of the underflow of streams having sandy beds. This is not to be recommended except in the case of rivers having large drainage basins and otherwise favorably situated for carrying a large underflow. As a general thing the water contained in deep and sandy stream beds, though large in amount, percolates but slowly, and the yield, if brought to the surface, would be small, and be secured at much cost.

OPERATIONS IN OREGON.

By JOHN T. WHISTLER.

Earlier reconnaissances and other investigations made in various parts of the State have been referred to at length in the Second Annual Report of the Reclamation Service, pages 433 to 444. A general study of artesian possibilities in central Oregon was made in 1903 by Israel C. Russell.[a]

MALHEUR PROJECT.

The Malheur project (Pl. LI) is located in the east-central part of the State along Malheur and Snake rivers. It contemplates the irrigation of about 90,000 acres of bench and bottom lands by storage in Harper reservoir and diversion at mouth of Malheur Canyon directly onto the western extremity of irrigable lands. Its elevation above sea level is 2,150 to 2,350 feet.

Preliminary investigations and surveys were made in 1903, and the results printed in Second Annual Report, page 434. These showed that as much as 75,000 acres, including land at present irrigated, could be brought under irrigation by a diversion at the mouth of Malheur Canyon about 12 miles above Vale. Surveys of Harper reservoir in the same year showed that a dam 160 to 170 feet high would impound nearly double the average run-off observed to that date—300,000 acre-feet.

WATER SUPPLY.

A gaging station on Malheur River, at Vale, had been maintained at intervals prior to May, 1903, by the United States Geological Survey. The station was established in 1890, and prior to investigations by the Reclamation Service a total record of a little over three years was obtained. Since then two, and for a short time three, stations on this river have been maintained, giving a total of nearly five years' records of discharge at Vale.

The maximum recorded discharge at Vale has occurred in the present year, 1904. The incomplete and unchecked record indicates that nearly 1,000,000 acre-feet of water will have passed down at the end of the year. Comparison with records from Bully Creek, at Vale, and 13 miles above, since May, 1903, show that not to exceed 15 per cent of this discharge is from Bully Creek, thus leaving more than 800,000 acre-feet of water, which would have been available from this year's run-off for storage above Bully Creek.

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[a] Geology and water resources of central Oregon: Bull. U. S. Geol. Survey No. 252, 1904

The minimum discharge recorded is that for 1890, when but 140,000 acre-feet passed by Vale. The average yearly discharge at this point, except that of the present year, which is generally regarded as unusual though probably not unprecedented, is approximately 300,000 acre-feet. This does not include diversions made above Vale, which might amount to 25,000 acre-feet additional.

Cable gaging stations are being maintained on Malheur River above and below the mouth of Bully Creek, as well as a bridge station on Bully Creek.

The station below Harper ranch is maintained by agreement with the Pacific Live Stock Company. The observer is provided by the company with the understanding that the data obtained will be available to it.

IRRIGABLE LANDS.

The surveys of irrigable lands during the last season show that probably 90,000 acres of land can be brought under the canals. The average run-off, including this year, which is admitted was unusual, is sufficient to provide more than 4 acre-feet for that amount of land.

The entire area under the highest possible canal lines has been mapped this year on a scale of 1,000 feet to 1 inch with contour intervals of 5 feet. The exact location of all improvements, including fences, ditches, roads, and houses, together with classification of cultivated lands, is shown. Areas where sidehill work is necessary have been mapped on a scale of 400 feet to 1 inch.

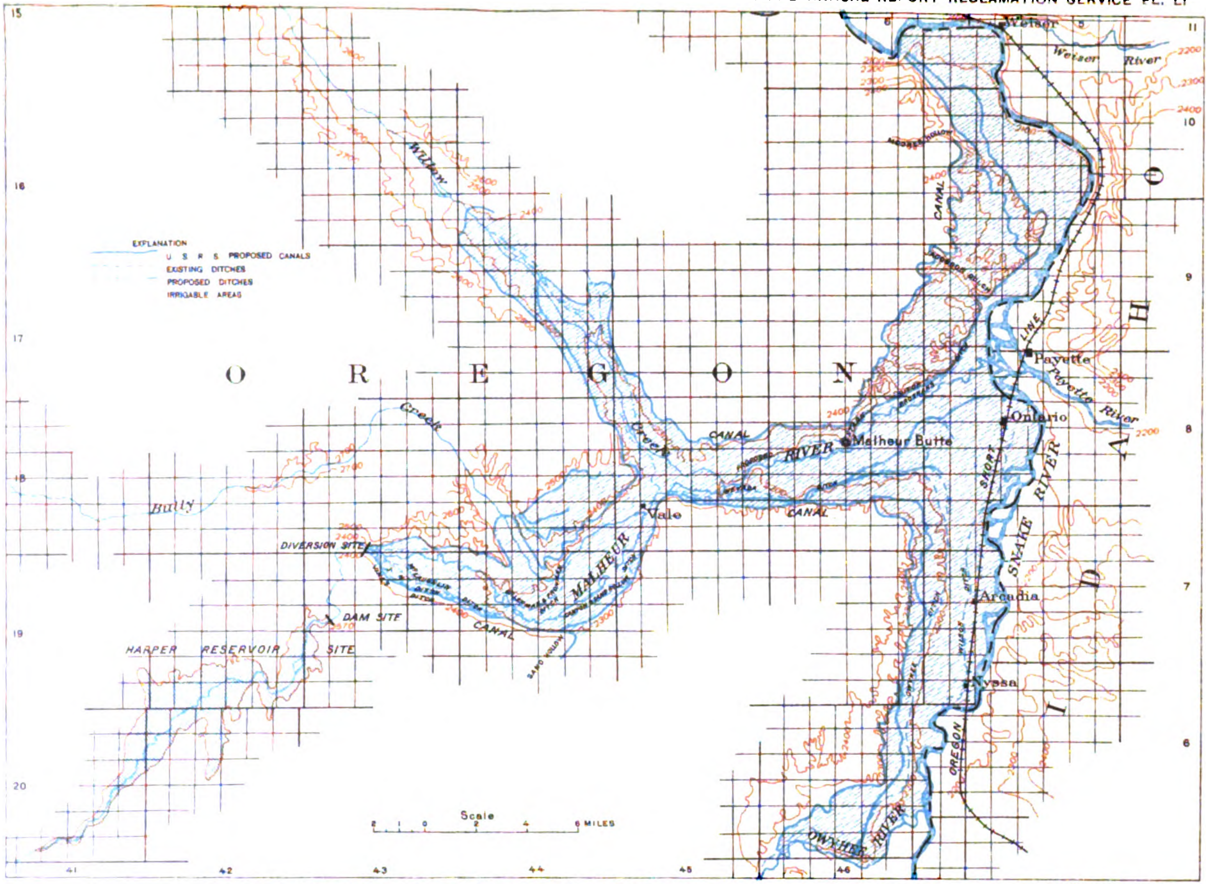
As improved and irrigated lands in these valleys now sell for $50 to $100 per acre, further investigation appears to be justified, and more detailed surveys of irrigable lands and dam sites for the Harper reservoir have been authorized.

About 85 per cent of the land falling under this project is patented, nearly 35 per cent being military road grant land.

Unpatented lands covering reservoir and diversion sites have been withdrawn from all entry; unpatented irrigable lands have been withdrawn from all except homestead entry under the reclamation act.

BORINGS AT DAM SITES.

Two diamond drills have been employed since the middle of July making borings at the dam sites below Harper ranch and Little Valley. The borings will not be completed before the end of the year, but results so far have shown rock at generally from 10 to 25 feet from the surface. The rock is basaltic and not entirely homoge-



GENERAL MAP OF PROPOSED MALHEUR PROJECT, OREGON.

A. HOEN & CO. BALTIMORE.

neous. It is believed that it may not prove best adapted to a foundation for masonry structure, but rather for a rock-fill structure with masonry core. By increasing the height of dam somewhat over that of the earlier estimates a natural spillway site can be utilized below Little Valley, and the dam may be constructed in a narrower canyon. Borings are now being made with this in view.

WATER USERS' ASSOCIATION.

The owners of patented lands have organized the Malheur Water Users' Association for the purpose of adjusting the present vested water rights and of managing other matters incident to obtaining water from a project under the reclamation act. The organization is along the lines of the Salt River Valley Water Users' Association, of Arizona. About 50,000 acres of land have been subscribed, by-laws adopted, and officers elected. Negotiations are now being undertaken looking to a settlement of the many more or less conflicting water rights in such a manner as to obtain the best results from the Government project. Many meetings have been held and some progress has been made toward a final acceptance of the project.

Two million dollars have been provisionally set aside from the reclamation fund for the construction of this project.

WILLOW CREEK PROJECT.

Willow Creek empties into Malheur River from the north near Vale. The lower 20 miles of the valley contain 20,000 to 30,000 acres of excellent land, which is at present unimproved for lack of water and largely unpatented. The north side canal under the Malheur project would cover a part of the lower end.

Since the flood run-off of the creek occurs early in the spring, any plan to use these waters must include provision for storage.

WATER SUPPLY.

Complete records of run-off on Willow Creek had not been obtained prior to May of this year. Stations on Malheur River above and below the mouth of Willow Creek, established in 1903, were intended for determining the discharge of this creek, but the lower one, which was on a highway bridge, was carried away with bridge last February. It has been estimated that the average yearly discharge is 50,000 acre-feet.

A gaging station has been maintained since May of this year at Cole's ranch, above Dell. A cable station is being erected also a few miles east of Malheur City, just below a proposed reservoir site.

RESERVOIR SITES.

A reconnaissance was made in 1903 of a reservoir site in the eastern part of T. 14 S., R. 41 E., and during the past season three sites have been examined. Surveys are being made, and it is thought that one site may prove feasible.

IRRIGABLE LANDS.

The land is similar to that under the Malheur project, and it is believed that it can stand a charge of $30 per acre. The irrigable land of the entire valley has been mapped this season in connection with the Malheur work. There is probably considerable more land than can be irrigated with the water supply available.

Not less than 10,000 acres of excellent bench land under this project are unpatented. Probably an equal amount of bottom land is patented, but is in great need of additional water supply during the latter half of the season.

Unpatented lands, covering two reservoir sites and a diversion site, together with two townships of irrigable lands, have been withdrawn from all entry; the remaining unpatented irrigable lands have been withdrawn from all except homestead entry under the reclamation act.

These lands were withdrawn under the Malheur project.

WATER USERS' ASSOCIATION.

Most of the patented land under this project was subscribed to the Malheur Water Users' Association and not to a separate organization, because the north side canal line under the Malheur project crosses Willow Creek Valley, and because it was thought possible that both projects might ultimately be considered together.

OWYHEE PROJECT.

Owyhee River empties into Snake River about 20 miles above the mouth of Malheur River. It would be practicable to irrigate perhaps 15,000 acres of land to the north and lying along the Snake from the Owyhee if storage were provided. It might also prove practicable to irrigate an equal or greater amount of land on the south side and along Snake River, partly in Oregon and partly in Idaho.

The elevation of these lands above sea level is the same as under Malheur project.

There are several excellent reservoir sites on the upper Owyhee, but the river for the most part flows through a canyon from 200 to 400 feet deep, and no practicable diversion can be made to cover any large body of land on either side, except at a great and probably prohibitive expense. The lands on the north side of the river can all be covered by water under the Malheur project.

A preliminary examination of possibilities of diverting water from this river was made early in 1903 and reported upon in connection with the Malheur project. Further investigation at that time was not recommended, because of the necessarily low diversion and because all of the land north of the river could be covered by the Malheur project if the water supply proved sufficient.

WATER SUPPLY.

The annual discharge from Owyhee River is nearly a half more than that of Malheur River. The minimum summer flow this year but little exceeds 150 second-feet; the mean minimum will probably but little exceed 100 second-feet.

The present Owyhee ditch, which diverts water at the mouth of the canyon, irrigates 5,000 to 6,000 acres somewhat unsatisfactorily in ordinary years. This is about the limit of the area possible to irrigate well without storage.

A gaging station was maintained at intervals from 1890 to May, 1903, since which time a regular station has been maintained and frequent measurements made.

SURVEYS.

This project has been considered only in connection with the Malheur project, and it appears probable that an arrangement can be made through the Malheur Water Users' Association to transfer the use of water from the present Owyhee ditch to a compact body of land of about the same area near Owyhee River instead of using it as at present on small tracts of land scattered along between Owyhee River and the Malheur at Ontario.

Surveys are being continued from the Malheur project across to the south side of Owyhee River, including all the area below the highest practicable diversion point on the river. Reconnaissance lines are also being run farther to the south to determine what area of land might be included if a higher diversion dam should be found practicable.

IRRIGABLE LANDS.

A very small portion of the area which can be irrigated from Owyhee River is unpatented. It would not in any case exceed 20 per cent.

All irrigable lands on the north side of the Owyhee have been withdrawn from all except homestead entry under the Malheur project. Most of those on the south side in Oregon have been withdrawn from all entry under the Owyhee project. The lands for a reservoir site, covering portions of Tps. 31 and 32 S., Rs. 41 and 42 E., have been withdrawn from all entry.

WATER USERS' ASSOCIATION.

Much of the land on the north side of the river has been subscribed to the Malheur Water Users' Association, since it also is being considered in connection with that project.

UMATILLA PROJECT.

The irrigable lands under this project lie west of Umatilla River and south of and bordering on Columbia River. The elevation of these lands above sea level is from 300 to 700 feet.

The project contemplates the use of flood waters from Umatilla River by storage, supplemented by any additional supply which can be obtained by diverting the flood waters of Willow Creek, or any of the tributaries of John Day River.

Since a practicable reservoir site could not be found in upper Umatilla Valley, a natural depression in T. 3 N., Rs. 25 and 26 E., was surveyed during the past season, and lines run, together with topography, for a feed canal from Umatilla River above Echo.

WATER SUPPLY.

Records of discharge of Umatilla River at Gibbon have been made since July, 1896. These records show that if storage can be had there is sufficient water supply for from 60,000 to 75,000 acres of land.

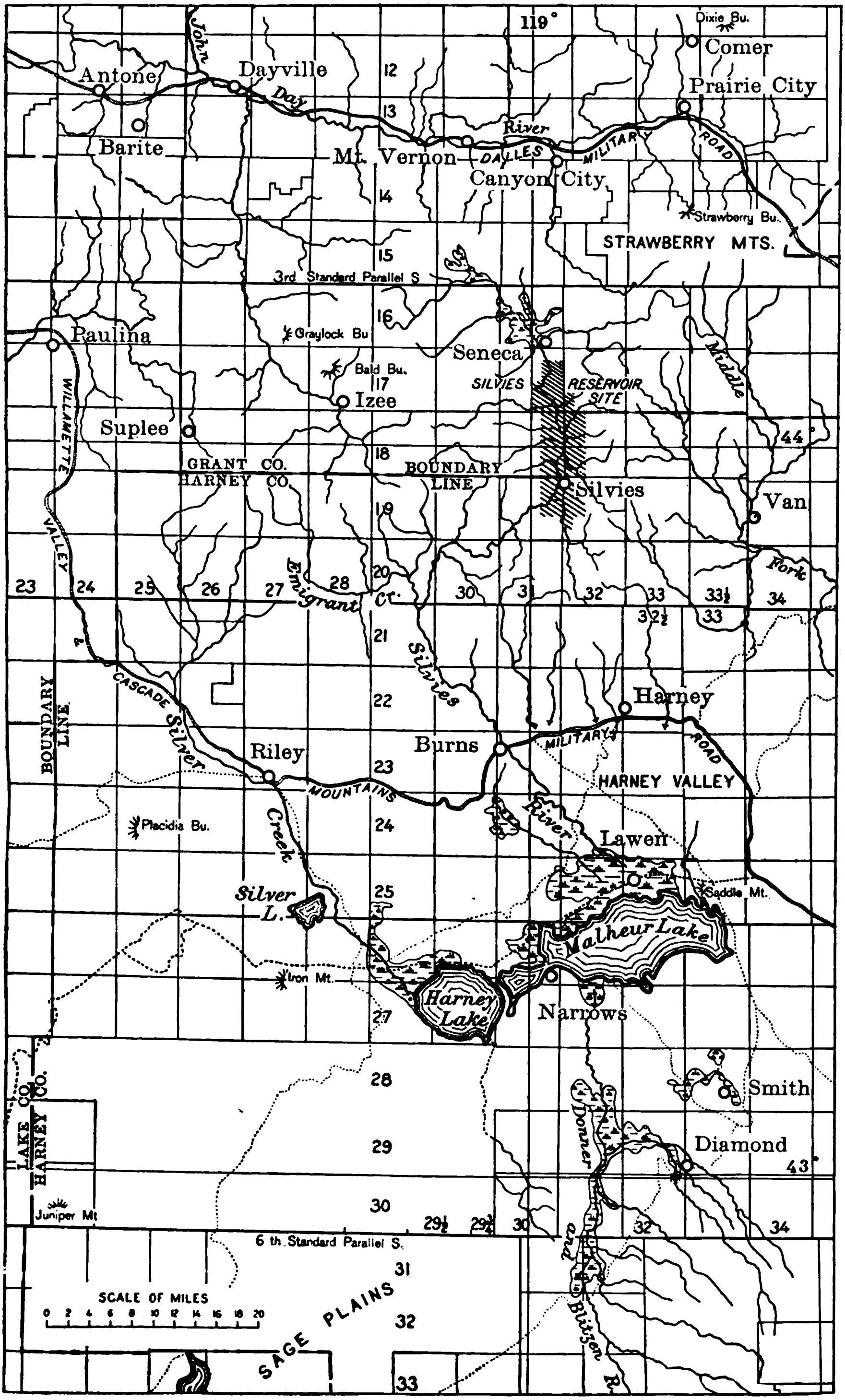
Since May, 1903, gaging stations have been maintained at Gibbon, Pendleton, and Yoakum railroad station, and on McKay Creek, near Pendleton.

In October, 1903, a cable station was established near the mouth of Umatilla River, the Oregon Land and Water Company undertaking to provide an observer at all times at an expense to the survey of not to exceed $5 per month.

IRRIGABLE LANDS.

An area of probably not less than 150,000 acres of land is available in this region if the water supply can by any means be increased so as to cover it.

The growing seasons are long and the winters short and usually mild. Four crops of alfalfa can be raised. In Butter Creek bottoms, with one flood irrigation, 3 crops of alfalfa are grown, yielding 5 to 8 tons per acre for the season. With these conditions it was felt the land could stand a possible charge of $35 per acre.



GENERAL MAP OF PROPOSED HARNEY AND SILVER CREEK PROJECTS, OREGON.

Of the total area of irrigable land under consideration, two-thirds, at least, is unpatented, and the major portion of patented land is Northern Pacific Railroad grant land. Both reservoir sites have been withdrawn from entry, and the irrigable lands have been withdrawn from all forms of entry except homestead entry. Some of the lands first withdrawn have been restored to entry.

PROGRESS OF WORK.

On March 1 of this year test pits were sunk at the present site and along the embankment and feed canal lines. The test pits in the reservoir site disclosed the fact that a not inconsiderable area of the lower part of the reservoir site and embankment was underlain by beds of coarse gray sand from 5 to 60 feet and more in thickness. For this reason the board of consulting engineers, after a careful examination, concluded that the reservoir site was impracticable and suggested search for others.

Another site similar to and immediately north of the one condemned by the board has been located, and examinations are now being made to determine its practicability.

Examinations have also been made to determine if there are any possible means of diverting water from John Day River over the divide onto these lands. This search has so far been entirely without success.

HARNEY PROJECT.

The Harney project (Pl. LII) contemplates the irrigation of lands in Harney Valley, which lies about 150 miles south and west from the mouth of Malheur River. Harney Valley is nearly round and has an area of approximately 700 square miles. It lies at an elevation of 4,150 feet above sea level, and has the appearance of having been at one time the bed of a lake, now shrunken to the present Malheur Lake. It is probable that the waters at that time emptied through a low gap, about 20 feet above the present surface of the lake, into Malheur River basin.

WATER SUPPLY.

Silvies River, emptying into this valley, and ultimately in flood season reaching Malheur Lake, carries a great deal of water for a short period during flood season.

Gaging stations were established in Silvies Valley and also below the mouth of Emigrant Creek in May, 1903, and were maintained until October 1, 1904. An arrangement has been made for continuing these stations, observers to be provided at the expense of the Harney Valley Improvement Company.

Measurements from May, 1903, to May, 1904, show that 250,000 acre-feet of water were discharged by Silvies River into Harney Valley, and that approximately half this amount was from Silvies River proper, and would be available at Silvies reservoir site for storage. It is recognized that this record of run-off covers a period of unusual precipitation and also that the rainfall in these interior basins is subject to great extremes.

The year's record shows that sufficient water could have been stored in Silvies reservoir to irrigate perhaps 60,000 acres if not required for irrigation under present uses. Under the present practice of flooding wild-hay lands, and of using from two to five times the water actually required if properly distributed, it is doubtful if in seasons of ordinary run-off there is more than sufficient water to satisfy present demands. Emigrant Creek alone, during the one year of which there is a record, furnished probably ample water for all the lands now cultivated, even under the present extravagant methods of irrigation. There is an excellent reservoir site in Silvies Valley about 20 miles north of Harney Valley.

IRRIGABLE LANDS.

There remain but about 60,000 acres of unpatented land in Harney Valley. This has been selected by the State, under the Carey act, for the Harney Valley Improvement Company.

Unpatented lands at the Silvies reservoir site have been withdrawn from all entry. The irrigable lands in Harney Valley were withdrawn from all except homestead entry in June, 1903, but were restored to entry in August of the present year.

The size of the channel of the river and a few measurements in May, 1903, before the flood waters had all passed down, and statements by residents of the valley as to usual length of flood water, indicate that 40,000 acres could be irrigated by storage of the entire flood waters of Silvies River at Silvies reservoir site. Owing to the high altitude the season is short, but the soil is rich and deep, and two crops of alfalfa can be grown.

ABANDONMENT OF THE PROJECT.

After a preliminary examination in April, 1903, topographic surveys of Silvies reservoir site and a large portion of the irrigable lands in Harney Valley were recommended. These surveys were completed in November, 1903. Early in June, 1904, a board of consulting engineers went over the ground and recommended that the project be abandoned, owing to probable insufficient water supply during ordinary seasons.

SILVER CREEK PROJECT.

WATER SUPPLY.

Little information of value as to the water supply available from Silver Creek could be obtained. The discharge was measured in September, 1903, but it has been impossible until recently to obtain a regular observer. From this measurement and the regular observations, it is estimated that the creek has, during the past year, discharged 100,000 acre-feet.

The flood water of this creek generally runs off so early that the storage of probably 75 per cent of the total discharge would work no injury to any of the land below and would increase the value of a great deal of it.

With this supply available it will be possible to irrigate 40,000 acres, but as the precipitation and run-off of the basin are subject to great extremes, it is thought probable that less than half that amount of land should be estimated upon. Perhaps double the amount of water required for this area of land should be provided for by storage. It is said there have been years when the creek carried almost no water.

A gaging station was established at the reservoir site in September, 1903. The observer shortly afterwards moved away, and the station was moved to Cecil's ranch, below the mouth of the canyon. The observer here also moved away during the spring, and after an intermission of some months a gage was placed on the bridge where the stage line crosses the creek, and observations are now being made by the stage driver on six days in the week. The station is by no means satisfactory, but the records, as obtained, appear to be reliable.

IRRIGABLE LAND.

The irrigable land under this project lies about and principally above Riley, in Silver Creek Valley, Harney County (Pl. LII).

There is a good reservoir site in T. 21 S., R. 26 E., below which for about 3 miles the creek runs through a comparatively narrow canyon. The valley then widens out and contains, between that point and Riley, perhaps 15,000 acres of bench and bottom land, which could be covered by a diversion at the mouth of the canyon. The land lies at an elevation of between 4,200 and 4,300 feet above sea level.

The soil appears to be very fertile, and the climate is similar to that of Harney Valley, though the bench lands are said to be practically free from midsummer frosts. It is believed that, owing to the short season and long distance from railroad, the land could not be charged more than $20 per acre for best water supply.

Probably not to exceed 20 per cent of lands which would come under this project are at present improved, and these lands grow only a light crop of wild hay, owing to the run-off of the creek occurring so early in the season and leaving little or no water by July 1. About one-third, however, of the land is patented through a military-road grant.

Unpatented lands covering the reservoir site were withdrawn from all entry and irrigable lands from all except homestead entry in July, 1904.

PROGRESS OF WORK.

The project was noted in a general reconnaissance made of the State early in 1903 and recommended for further investigation. This year a topographic survey was made of the reservoir and dam sites, and lines are now being run to determine just what area of land can be brought under a diversion at the mouth of the canyon.

CHEWAUCAN PROJECT.

The lands for the Chewaucan project (Pl. LIII) lie generally north and east of Paisley and Chewaucan Marsh, in the south-central part of the State. Their elevation is approximately 4,500 feet.

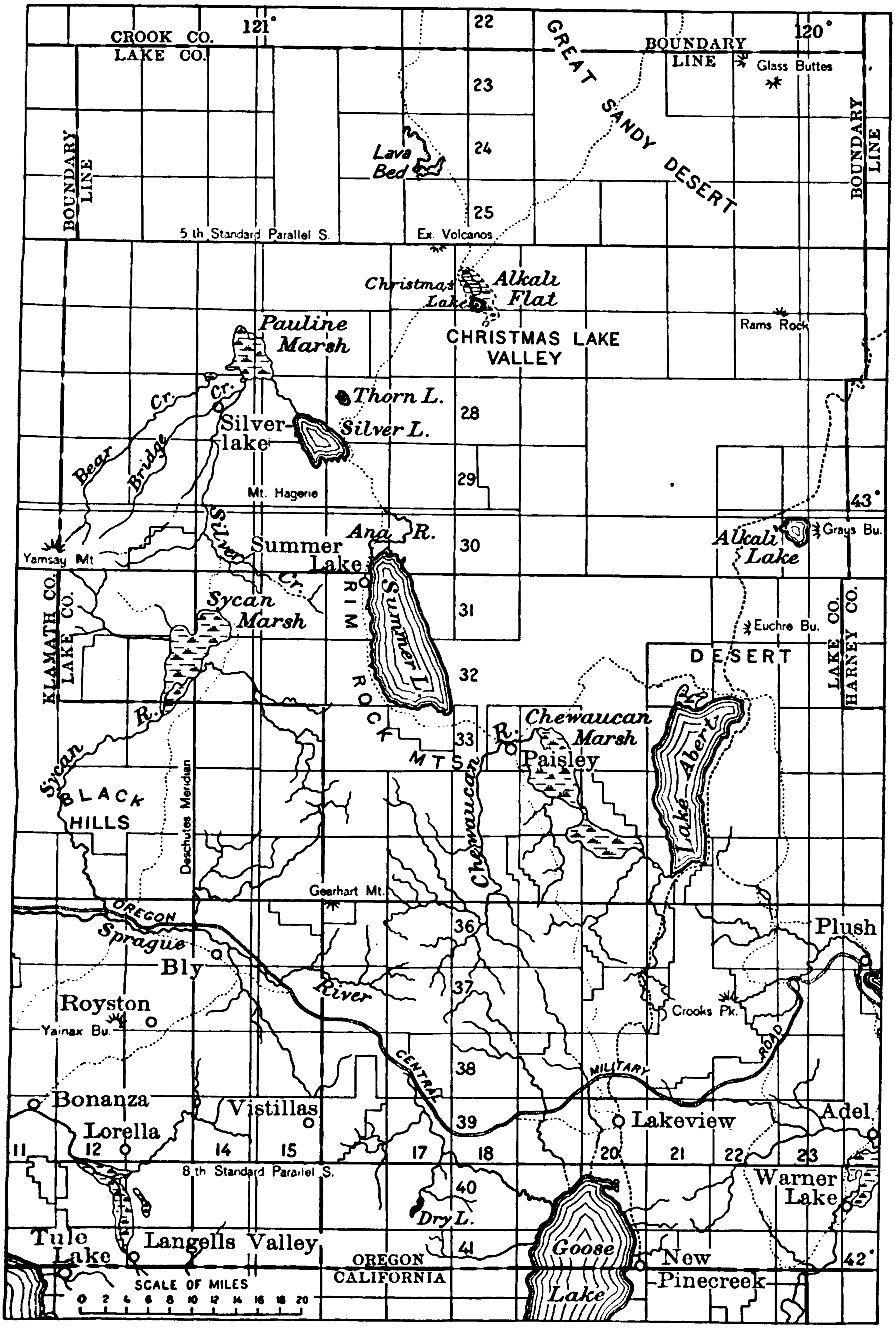
Chewaucan River empties its entire volume of water through a narrow canyon into Chewaucan Marsh, which is owned almost entirely by the Chewaucan Land and Cattle Company. At a considerable expense channels are being cut around and through the marsh to carry off the flood waters and so reclaim large areas of the marsh land. Chewaucan River empties into this marsh much as it would into a lake, and it is a remarkable fact that there is no natural channel or slough. From the marsh the water empties into Abert Lake, a body of water without an outlet, having an area of between 80 and 90 square miles. Its principal source of supply to make up for losses by evaporation is from waste waters of Chewaucan River.

The lands to the east and north of Chewaucan Marsh are very fertile and, for this altitude, unusually free from frosts.

WATER SUPPLY.

Measurements made during June and July of this year, in connection with a water suit in the latter part of October, 1898, reliable statements regarding duration of floods, and the high-water marks indicate that the maximum discharge of Chewaucan River at Paisley is 250,000 acre-feet. A discharge of over 800 second-feet was measured this year, on June 16.

The Chewaucan Land and Cattle Company, owning Chewaucan Marsh, is vitally interested in any project for storing water and relieving their lands of most of the spring floods.



GENERAL MAP SHOWING PROPOSED CHEWAUCAN, ANA RIVER, AND SILVER LAKE PROJECTS, OREGON.

Miscellaneous gagings only have been made during this season, but stations will probably be established on Chewaucan River at the diversion point and also below Chewaucan Marsh. Mr. W. J. Taylor, manager for the Chewaucan Land and Cattle Company, has offered to furnish voluntary observers for these stations.

IRRIGABLE LANDS.

The area of irrigable land which can be covered by a gravity system is about 33,000 acres.

There was apparently at one time a broad channel from Summer Lake to Chewaucan Marsh and Abert Lake basin. By crossing this with a long pipe line it will be possible to cover 40,000 acres of land additional.

The State has applied for the withdrawal under the Carey act of about 14,000 acres of the 33,000 acres above referred to. If this is allowed, it will probably prove impracticable to undertake the project for the remainder.

Owing to the high elevation, late frosts frequently occur in the bottom lands and prevent the general cultivation of such vegetables as tomatoes and potatoes. Along the foothills, however, in the more protected places, all the fruits and products of the ordinary garden are grown. Two crops of alfalfa are now successfully raised.

It is not believed that these lands, remote as they are from railroads, could at present stand a charge for even a storage supply of more than $20 per acre.

PROGRESS OF WORK.

Surveys have been made during the past season of two reservoir sites in upper Chewaucan Valley. One of these, with a 100-foot dam, will store 130,000 acre-feet, and the other, with a dam of the same height, will store 95,000 acre-feet. Preliminary lines were also run from a diversion point at the lower end of the canyon to determine the amount of land which could be covered.

The withdrawal from all entry of irrigable lands under this project, together with reservoir sites and diversion site, has been requested. Probably not 15 per cent are patented.

ANA RIVER PROJECT.

This project (Pl. LIII) lies northwest of Chewaucan project and north of Summer Lake, in south-central Oregon, and has an elevation of about 4,500 feet above sea level.

Ana River rises in 5 large springs in the W. ½ of sec. 6, T. 30 S., R. 17 E., and flows south into the north end of Summer Lake, about 5 miles distant. The lower pool or spring is about 25 feet above the surface of Summer Lake, and the river for a mile or more flows through a narrow canyon from 30 to 50 feet in depth, cut in a soft, whitish earth or volcanic ash.

WATER SUPPLY.

The discharge from the springs is said by people in that vicinity to be constant. A measurement made in July of this season showed 155 second-feet. With this supply it is estimated that 12,000 to 15,000 acres could be irrigated. The temperature of the water as it flows from the springs is from 65° to 68° F.

No gaging station will be established unless a series of measurements show the supply from the springs to vary.

IRRIGABLE LANDS.

On the west side of Summer Lake fruit and garden produce of all kinds are grown in abundance. The area that could be irrigated from Ana River should have the same climate as Summer Lake, except that it would be more subject to winds.

The soil in places is very alkaline, and much of it is covered with sand dunes. With water at this temperature and running the entire season it is believed that all alkali can easily be taken care of and that a sufficient amount of level land can be found to at least justify further investigation. It is believed that for this water supply the land will easily stand a charge of $20 per acre. The lands under this project are practically all unpatented.

Pending further investigation, the lands covering the diversion of this river have been withdrawn from all entry and the irrigable lands from all except homestead entry.

PROGRESS OF WORK.

Surveys have been made this season of the sources of Ana River, and preliminary lines run to determine the available area for irrigation. A preliminary estimate has been made, based on these surveys, for raising the water 70 feet by a dam and diverting it over the better alkaline lands.

SILVER LAKE PROJECT.

The land for this project (Pl. LIII) lies north of Silver Lake, in Lake County, and is what is locally known as the Low Desert, or Silver Lake Desert. There have also been included lands west of Silver Lake.

The lands of Silver Lake Desert are a little lower than Silver Lake, which discharges a greater or less amount of water in different years toward Thorn Lake.

There is said to be a reservoir site on upper Silver Creek, from which lands west of Silver Creek may be irrigated.

The general elevation of this region is about 4,700 feet above sea level.

WATER SUPPLY.

Practically nothing is known of the water supply available, but it is said that water can be found at a little depth below the surface over the Silver Lake Desert. A fresh-water well on the border of Christmas Lake indicates that here and at Thorn Lake the water table is probably near the surface, and that there is a constant flow to these lower places. Silver Lake water is entirely fresh, showing that this year's discharge is not unusual at least. It is said that the wild-hay lands of Pauline Marsh would be materially improved if a portion of the flood waters could be diverted. Not even an approximate estimate of the area possible to irrigate or of the cost can be made until measurements of the discharge of the streams emptying into Pauline Marsh have been made.

CLIMATE.

The climate in this region is more severe than in the Summer Lake and Chewaucan regions. Frosts occur every month in the year and snow is said to drift a great deal in winter. It is not probable that the land so remote from railroads and with such a climate, could stand a charge for water of more than $15 per acre. Practically all of the land of Silver Lake Desert is unpatented. Of that west of Silver Lake probably half is patented.

PROGRESS OF WORK.

No surveys have yet been made. Gaging stations may be established on the streams flowing into Pauline Marsh and at the outlet of Silver Lake.

The withdrawal from all entry of lands bordering on Silver Lake, and of all irrigable lands from all except homestead entry under the reclamation act, has been requested.

ODELL AND CRESCENT LAKES PROJECT.

This project contemplates the storage of the flood waters of Odell and Crescent lakes and of the East Fork of Deschutes River, and their diversion across the Walker Mountains onto the Silver Lake Desert, as described under the heading "Silver Lake project."

WATER SUPPLY AND IRRIGABLE AREA.

No record of the discharge of the two lakes or of the stream is available, and estimates of the water supply are from miscellaneous measurements made this season. From these it was estimated that 400,000 acre-feet of water might be obtained. Since the canal line would be from 70 to 80 miles long and through a porous, pumiceous soil, it is possible that not over 25 per cent of available supply would reach the land. Assuming 1½ acre-feet sufficient for each acre, 65,000 acres could be irrigated.

As this project may prove of value in later years with railroads through the interior, gagings will be continued to determine the actual water supply available.

PROGRESS OF WORK.

Preliminary surveys were made during the season of the sources of supply, and a line run across the divide to the lands. By holding the grade to the minimum consistent with cost, the divide could be crossed with a tunnel of 4,000 feet.

If it could be shown that the loss of water in the long canal by seepage and evaporation would be less than 50 per cent, the project might be practicable. It certainly would with a railroad into this section to raise the value of irrigated land.

The present value of this land, which is practically all unpatented, with water, is referred to under the Silver Lake project, pages 474–475.

As further consideration of this project is not recommended, no withdrawal of lands has been requested.

OPERATIONS IN SOUTH DAKOTA.

By Raymond F. Walter.

Investigations in this State have been carried on only west of Missouri River, which divides the State near the center. The part to the east of the river does not need irrigation except in dry years, but that to the west is mostly barren and devoid of cultivation except where irrigated. Its principal industries are cattle raising on the plains and mining in the hills.

The Black Hills are located along the line between Wyoming and South Dakota. From them numerous streams rise and flow in a general easterly direction to Missouri River.

There are no records of the flow or run-off prior to the summer of 1903, since which time daily records have been kept and reconnaissances made on the most important streams. The records of the run-off are published in the progress reports of the United States Geological Survey. Thirteen regular stations are maintained in this work and miscellaneous ratings made throughout the year.

BELLE FOURCHE PROJECT.

Belle Fourche Valley is situated northeast of the Black Hills in the northwestern part of South Dakota. It is reached by the Chicago and Northwestern Railroad, which enters the town of Belle Fourche by a branch line from Whitewood. The Burlington and Missouri River Railroad runs to Spearfish, 14 miles south of Belle Fourche, and the Wyoming and Missouri River Railroad runs from Belle Fourche to the coal fields at Aladdin, Wyo.

The valley lies in Butte and Meade counties, and the principal towns directly benefited by the construction of the Belle Fourche project (Pl. LIV) would be Belle Fourche, which is near the head of the valley; Sturgis, which is south of the lower end, and Whitewood, which is at the railroad junction.

The elevation of the valley is about 3,000 feet at the upper end and 2,600 feet above sea level at the extreme lower end.

There is little irrigation in the valley, except in a small area along Redwater River, where about 4,000 acres are cultivated. Alfalfa, grain, potatoes, and small fruit are raised successfully. In the general reconnaissance of the Black Hills area it was found that Dry

Creek, a small dry stream, instead of running with the general fall of the country, takes a northerly course and empties into Owl Creek several miles from the main river. A high ridge or divide separates the watershed of Dry Creek from that of the river, the bluff extending unbroken on all sides to a point near the mouth of the creek, where a dam about 3,000 feet long would impound a large body of water if connection could be made by an inlet canal with the main river. To the east of this basin lies a body of land which could be easily watered by a distribution system from the reservoir. Preliminary surveys were begun July 18, and it was found feasible to fill the basin by a canal heading at the town of Belle Fourche. A small party was organized and a careful investigation conducted during the summer of 1903. A board of engineers, consisting of A. P. Davis, J. H. Quinton, and C. H. Fitch, examined the project in April, 1904, and ordered detail surveys of the irrigable area, dam sites, and canal lines.

The plan as outlined contemplates the reclamation of land on both sides of the Belle Fourche River below the reservoir, all being under the storage system except about 4,000 acres, which are under the inlet canal only.

Of the area between the canals and the river about 50,000 acres are in private ownership, mostly lying along the river and creek bottoms.

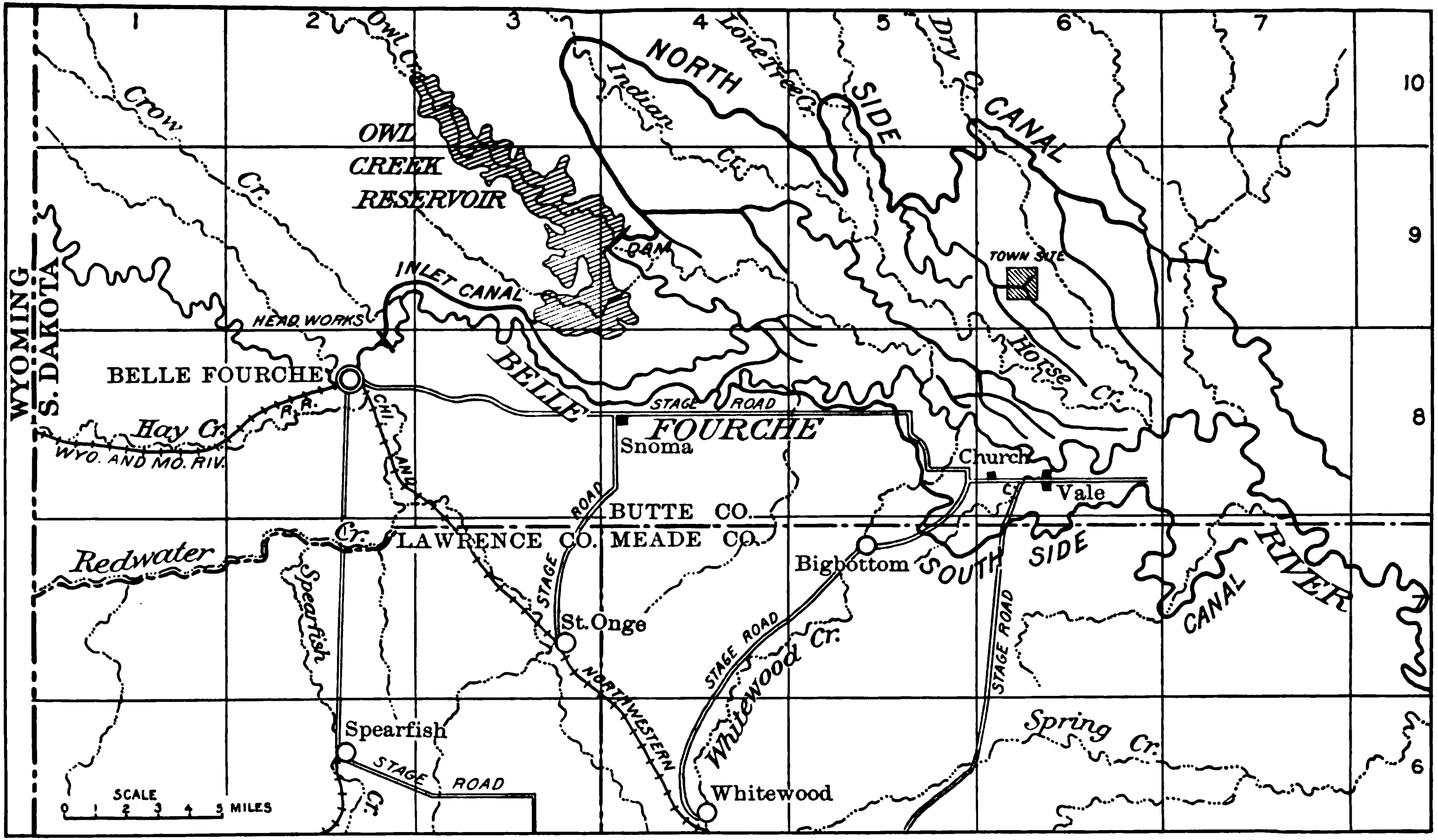
An association of landowners was formed June 1, 1904, known as the "Belle Fourche Valley Water Users' Association." Articles of incorporation were adopted and accepted by the Secretary of the Interior. About two-thirds of the private lands under the canal have been subscribed up to the present time. The rest is held mostly in large holdings or by nonresidents, who are subscribing very slowly.

RESERVOIR SITES.

An investigation of the best location of the dam for the main storage reservoir was taken up and three possible lines investigated: No. 1, across Dry Creek, about one-half mile above its junction with Owl Creek; No. 2, across Owl Creek, just below the junction; No. 3, across Owl Creek, one-half mile below the junction. A dam at No. 1 would be shorter and higher than at the other sites; it would back water on Dry Creek only, while the other two would produce reservoirs on Owl Creek as well.

Contents of dam and capacity of reservoirs on Owl Creek.

Line.	Elevation.	Embankment.	Slope.	Capacity.
	Feet.	*Cubic yards.*	*Sq. yards.*	*Acre-feet.*
No. 1	2, 990	1, 810, 800	99, 130	157, 000
No. 2	2, 980	2, 070, 760	109, 932	246, 000
No. 3	2, 980	2, 286, 324	111, 000	248, 000



GENERAL MAP OF BELLE FOURCHE PROJECT, SOUTH DAKOTA.

The above estimates were based on a dam 16 feet wide on top, 3 to 1 slope inside and 2 to 1 slope outside. Line No. 2 was finally adopted as the cheapest and most feasible, and estimates were made for the contents of a dam there for different heights and different slopes, as follows:

Contents of dam on line No. 2 with different slopes and different heights.

Contour.	Slope 3-1 and 2-1, top width 16 feet.		Slope 2-1 and 2-1, top width 16 feet.		Slope 1½-1 and 2-1, top width 20 feet.	
	Embankment.	Slope.	Embankment.	Slope.	Embankment.	Slope.
Feet.	*Cubic yards.*	*Sq. yards.*	*Cubic yards.*	*Sq. yards.*	*Cubic yards.*	*Sq. yards.*
2,980	2,070,760	109,932	1,712,311	77,983	1,574,426	62,634
2,975	1,781,481	99,177	1,473,285	70,416	1,359,132	56,505
2,970	1,516,148	88,400	1,258,403	62,764	1,163,537	50,355
2,965	1,280,044	78,078	1,062,437	55,436	988,493	44,507
2,960	1,070,807	68,311	888,770	48,500	832,925	38,918

OWL CREEK RESERVOIR.

From surveys and study of the results it was found that a dam on the line across Owl Creek just below the mouth of Dry Creek would be the cheapest and would supply sufficient water for the complete irrigation of all lands in the project on both sides of the river.

The dam will be of earth and when completed will be one of the largest earth embankments in the United States. It will be 100 feet high in the highest place, 1 mile long on top, 20 feet wide on top with 1½ to 1 water slope, which will be completely paved with stone to a depth of 18 inches. The outer slope will be 2 to 1. The conduit or controlling gates will be placed in a concrete well located in the center of the fill, connecting with the reservoir and the distributing canal by a three-arch concrete conduit of sufficient capacity to fill the canal when the reservoir is low. In the well three steel gates will control the outflow.

When the reservoir is full the area of the water surface will be nearly 9,000 acres and the water will be 60 feet deep.

The earth available for the dam construction is clay containing a small quantity of gravel, and will make a first-class embankment. The material is in high hills at each end and is convenient for handling. Borings show a depth of 40 feet of earth before bed rock is reached in the reservoir.

All water for irrigable lands except the small quantity used under the main supply canal will be drawn through this reservoir.

Capacity of Owl Creek reservoir at different contours.

Contour.	Area.	Capacity of section.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
2,920	583	....	....
2,925	875	3,644	3,644
2,930	1,240	5,287	8,931
2,935	1,640	7,199	16,130
2,940	2,084	9,309	25,439
2,945	3,031	12,786	38,225
2,950	3,852	17,207	55,432
2,955	4,641	21,232	76,664
2,960	5,573	25,535	102,199
2,965	6,349	29,806	132,005
2,970	7,174	33,806	165,811
2,975	8,010	37,959	203,770
2,980	8,888	42,246	246,016

WILSON RESERVOIR.

Another site, known as the "Wilson reservoir," was investigated; but if the main reservoir is so constructed as to give storage for all the lands it is believed this will not be needed, there being only a small part of the area under it. The following table shows its area and capacity:

Capacity of Wilson reservoir at different contours.

Contour (assumed).	Area.	Capacity of section.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
100	400	....	....
105	510	2,702	2,702
110	688	2,994	5,696
115	856	3,858	9,554
120	1,022	4,696	14,250
125	1,209	5,576	19,826
130	1,348	6,391	26,217

MAIN SUPPLY CANAL.

The main supply canal has a length of 6.45 miles, grade 1.056 feet per mile, bottom width 40 feet, and side slopes in excavation 1 to 1. It will carry a depth of water of 10 feet and its capacity will be 1,635 second-feet.

The soil in which the canal is to be built is clay, through which the loss by seepage will be very small.

Two lines for canals were investigated, one heading at mouth of Redwater River and needing simply a diverting dam; the other heading about 1 mile below the mouth of Redwater River and about 1½ miles below Belle Fourche. This head will necssitate a dam to raise the water 8 feet to the canal grade. The foundation at this place was found to be shale, and the cost of the dam was found to be less than the construction of the mile of heavy work necessitated by the first line surveyed. It will also give a much better foundation for headworks. A small pond or lake will be formed above the head of the location adopted and will make an ideal settling basin.

The dam and regulator are to be of concrete and steel. Water to a depth of 6 feet may flow over the crest of the weir, which is 400 feet long and gives an overflow capacity of 20,000 second-feet before the flood-water level is reached.

Where the canal crosses Crow Creek flood gates and an overflow weir will be located. This structure will be of concrete with steel gates and will discharge 6,000 second-feet of water and also act as a sluice for head of canal.

The canal enters the reservoir through a 40-foot cut. As the canal is in shale, the water can probably be dropped into the reservoir with safety.

The inlet canal and a lateral therefrom will reclaim about 4,000 acres of land along the river above the reservoir.

HIGH-LINE CANAL.

A preliminary survey was made of the extension of the main supply canal as far as Horse Creek. This line was found to be very long and ran through a very rough country. On upper Owl and Indian creeks about 15,000 acres of irrigable lands lie under it and above the distributing canals from the reservoir, but as this land would not be supplied with storage, it was thought best to abandon it unless it could be reached by pumping with power developed at the reservoir. As the outlet canal from the reservoir has 20 feet drop below the tunnel a high-line lateral may be run across Indian Creek flat to cover part of this land, and if the water supply prove sufficient later, power may be developed at the reservoir and water raised to the balance. This land mostly belongs to the Government.

A reconnaissance of the upper waters of Belle Fourche River was made in June, 1904, for possible storage on the river which might be cheaper than the Owl Creek reservoir or might be needed in addition to it if it were decided to extend the canal below Willow Creek. No dam sites were found, however, and any possibility of large storage there had to be dropped.

DISTRIBUTION SYSTEM.

From the Owl Creek reservoir two distributing canals will be needed, each about 40 miles long.

NORTH SIDE CANAL.

The larger canal will run from the reservoir in a northerly, then easterly, direction, irrigating land on the north side of the river between the reservoir and Willow Creek divide. This canal will water about 60,000 acres and will have at its head a bottom width of 26 feet with side slopes of 1 to 1 in excavations, and will carry a depth of water of 7 feet with a grade 1.056 feet per mile. It will be built in clay, through which there will be little seepage. There is no rock work on the line, although shale may be encountered in places.

From this canal water is diverted through seven large laterals, or branches, to lands distant from the canal.

A high-line lateral may be built from this main canal to cover lands on Indian Creek flat above the main canal, as there will be 20 feet drop in the canal below the cut through the ridge 1½ miles below the reservoir. This lateral will water 2,600 acres.

There will be but one right of way to buy on this canal line.

From Willow Creek, where, according to the plans, the main canal will terminate, a preliminary survey was run to see what land could be reclaimed below the Willow Creek divide and to ascertain the cost of its reclamation. It was found, however, that on account of the length of the line and the extreme roughness of the country it will run through it will not pay to bring these lands under the project at this time. About 30,000 acres of land can be reached by this extension, and as the land becomes more valuable above and the demand for it increases these lands may be reclaimed by the extension. They have all been withdrawn.

SOUTH SIDE CANAL.

A canal which will leave the reservoir on the west side of Owl Creek will irrigate about 4,000 acres on lower Owl Creek, emptying the stored water into the river below the point where another diversion is made to irrigate about 20,000 acres of first-class land on the south side of the river in the vicinity of Vale and Empire. This land is mostly in private ownership.

By making a second diversion from the river here instead of fluming or siphoning the stored water across the river the return water from the land irrigated above may be used and at times plenty of water can be secured from the river direct and the stored water saved.

The soil in which this canal runs is mostly clay, but there are some gravel banks and steep side-hill work in places. About 4 miles below the diversion from the river a high-cut bank is encountered, through which it will be safer to tunnel for 1,400 feet.

The first section of the canal will be 16 feet wide on the bottom, side slopes in excavations 1 to 1, depth of water 5 feet, and grade 1.5 feet per mile, giving a capacity of 243 second-feet.

The following table gives the capacity and dimensions of the canals:

Canal dimensions.

Canal.	Bottom.	Slopes.	Depth.	Grade per mile.	Velocity.	Capacity.
	Feet.		*Feet.*	*Feet.*	*Second-feet.*	*Cubic feet.*
Main supply	40	1 to 1	10	1.056	3.27	1,635
North side:						
Section 1	26	1 to 1	7	1.056	2.52	582
Section 2	24	1 to 1	7	1.056	2.48	538
Section 3	22	1 to 1	7	1.056	2.45	497
Section 4	18	1 to 1	7	1.056	2.37	415
Section 5	8	1 to 1	5	2.11	2.41	156
South side:						
Section 1	16	1 to 1	5	1.50	2.30	243
Section 2	12	1 to 1	5	1.056	2.04	220
Section 3	12	1 to 1	5	1.50	2.20	186
Section 4	10	1 to 1	5	1.50	2.20	161
Section 5	10	1 to 1	4	1.50	2.00	106

LATERALS.

The land on the north side is rolling in places, requiring numerous laterals, and in other places is very flat, requiring drainage ditches.

A paper location of this system will be made from the land survey sheets during the coming winter and the cost determined.

IRRIGABLE LANDS.

About 150,000 acres of land lie between the distribution canals and the river, on both sides of the river, of which about 90,000 acres are first-class irrigable lands. These lands have been classified, and they have been mapped on a scale of 1,000 feet to 1 inch with 5-foot contour intervals.

The statement following shows the number of acres of irrigable land on both sides of the river, the areas in public and private ownership, and the area subject to reclamation.

Estimate of irrigable lands.

	North side of river.	South side of river.	Total.
	Acres.	*Acres.*	*Acres.*
Land under canal and laterals	77,075	19,888	96,983
Less waste land 10 per cent	7,709	1,988	9,697
Balance irrigable	69,386	17,900	87,286
Land in school and public ownership	45,000	1,000	46,000
Land in private ownership	25,784	16,900	42,684
Total	70,784	17,900	88,684
Private lands not subscribed October 15, 1904	9,530	5,650	15,180
Subject to reclamation act	61,254	12,250	73,504
Overflow lands (included in waste)	3,460	265	3,725

The overflow lands are irrigable, but are subject to overflow. In some years good native hay can be raised without irrigation, and as the lands are all in private ownership, some of the owners do not wish to subscribe or pay for water from the canals for them.

The land it is proposed to irrigate is mostly what is locally known as "gumbo land"—that is, heavy clay soil—and takes much less water than the sandy soil. Some of the land will take considerable labor to get it in condition for irrigation, as it must be worked when it is neither too wet nor too dry. The soil is all first class, and is free neither too wet nor too dry. The soil is all first class, and is free from alkali, waste spots, and rock or gravel. All the land that is under the creeks, on which good native hay can be produced. The land on the south side is more sandy than that on the north side. In places the land is very flat, while in other localities it is extremely rolling, necessitating quite an extensive distribution system.

During high floods silt is apt to be an element of some trouble, but it is always in suspension and not of a rolling character, so that when carried direct to the lands it will be beneficial.

T. H. Means, engineer of soils, visited the lands and reports that very little drainage will be needed and that the lands can be classified and farm units made from the plane-table sheets, as the soil is all first class.

The crops that can best be raised are small grains—such as oats, wheat, rye, and barley—and fruits—such as apples, pears, plums, and cherries. Sugar beets would no doubt prove a profitable crop if a factory for making sugar was located in this locality. Potatoes can be raised on the south side, where the land is more sandy The main crop, however, will be hay, both native and alfalfa, for which there is a great demand as winter feed for cattle and sheep, which have the large range to feed on during the summer.

Alfalfa produces with water 3 crops and will average, it is said, at least 5 tons per acre, worth at least from $4 to $5 per ton in the stack as feed for cattle.

The season for irrigation and growing is rather short and the water supply must be the best, so that the crops will not be set back for want of moisture when they need it. This season will generally open May 1 and end about September 15.

The demand for farm and garden produce is great in this part of the State, especially in the mining regions, where these always bring the highest prices. As a very small amount of freight is shipped out of this region and as the railroads have to haul empty cars east, this produce should then be transported east at low rates.

The value of the lands as now used for grazing is from $2.50 to $5 per acre. The farm unit recommended under the project is 80 acres, which will be reduced to 40 acres within 3 miles of towns or proposed towns.

Sec. 29, T. 9 N., R. 6 E., has been reserved for a town site under the first form of withdrawal, pending investigation and survey. This proposed town site is located near the center of the irrigable area and will be about 20 miles east of Belle Fourche and a like distance north of Sturgis, S. Dak.

WATER SUPPLY.

The water supply for the proposed irrigation is mostly from the run-off of the northern and western part of the Black Hills.

The areas of the drainage basin of the streams at the points of diversion are as follows:

Drainage area of streams at points of diversion.

	Square miles.
Belle Fourche River	3,250
Redwater River	1,015
Crow Creek	125
Owl Creek	170
Indian Creek	320
Horse Creek	80
Total	4,960

PRECIPITATION.

The monthly precipitation at Bellefourche, as recorded by the United States Geological Survey, during the summer of 1904 was, May, 1.94 inches; June, 4.68; July, 0.42; August, 2.32; September, 0.23; October 1 to 15, 2.55.

The monthly precipitation in the Black Hills, as given in the rec-

The monthly precipitation in the Black Hills for the past ten years, as given in the records of the United States Weather Bureau, is shown in the following tables. Rapid and Fort Meade are at the edge of the Black Hills on the plains and Spearfish and Silver City are in the mountains.

Monthly precipitation, in inches, at Rapid, S. Dak.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1888	0.33	1.62	1.76	0.41	6.01	4.74	1.69	4.16	0.02	0.43	0.47	0.47	22.11
1889	.52	1.39	.52	4.22	2.19	2.97	4.62	.11	.37	.43	.32	.32	17.98
1890	.47	.66	1.40	1.55	2.45	3.77	.13	1.83	.75	.56	.27	.27	13.01
1891	.27	.87	1.96	2.74	1.72	3.25	2.09	1.97	1.32	.34	.17	.17	16.87
1892	.63	.24	1.18	4.04	4.49	3.80	.67	2.00	.13	2.29	.08	.08	19.63
1893	.30	.45	.92	1.05	1.73	1.21	1.51	.63	.06	1.01	.36	.35	9.58
1894	.41	.17	1.18	4.34	.72	4.17	1.31	.35	.65	.16	.34	.34	14.04
1895	.25	.27	1.95	1.53	2.06	6.22	.39	.68	.36	.02	1.03	1.03	16.39
1896	.27	.22	1.35	1.67	.60	3.35	1.73	.13	2.58	.68	1.09	1.09	14.76
1897	.62	.46	1.69	.69	1.82	2.67	.71	2.15	.08	.15	1.16	1.16	13.36
1898	.56	.24	.51	1.06	3.26	.50	1.50	.72	1.27	.63	.06	.06	10.97
1899	.33	.41	.94	.43	6.76	2.95	.96	.52	.83	.51	.19	.81	15.64
1900	.33	.17	.45	3.81	.73	2.13	1.45	1.64	2.09	1.58	.34	.14	14.66
1901	.31	.58	.40	1.86	2.53	7.53	4.83	2.52	1.30	.26	.14	.38	22.59
1902	.18	.14	3.34	2.49	2.97	2.96	3.59	.72	.43	.21	.68	.80	18.51
1903	.23	.47	1.10	3.51	2.94	3.79	7.37	2.47	2.79	.30	Tr.	.31	21.28
1904	.46	1.00	.40	.43	3.50	5.07	1.84	1.36	.43				
Normal													16.34

Monthly precipitation, in inches, at Fort Meade, S. Dak.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1879							0.78	1.40	0.14	1.60	0.04	0.89	
1880	0.38	1.00	0.92	0.75		4.68	1.62	3.91	Tr.	.54	.44	.39	
1881	.56	1.30	.95	1.10	3.33	2.66	1.50	1.57	1.00	.63	.46	Tr.	15.06
1882	.10	.10	.60	4.77	3.87	5.47	3.05	.44	.26	.49	.05	.12	19.32
1883	2.90	.30	2.16	4.50	9.61	1.56	2.80	.18	1.60	.67	.05	.72	27.05
1884	.37	.33	2.26	5.04	8.58	.48	1.20	2.30	.23	.75	.53	.90	22.97
1885	.32	.23	.52	1.30	.64	3.38	1.52	3.22	.28	.74	.93	.17	13.25
1886	.32	.67	.88	2.17	.57	.90	3.38	1.50	.40	.40	1.60	.72	13.51
1887	.56	.20	.76	2.12	2.72	1.76	4.46	4.25	1.10	.40	.25	.36	18.93
1888	1.65	1.29	.75	.20	3.91	5.50	2.64	3.54	.02	.14	.16	.17	20.00
1889	.27	.85	.12	2.64	2.02	1.60	6.38		.67	1.71	.88	.86	18.00
1890	.55	.46	1.21	1.65	2.31	6.30	.16	1.64	.76	.88	.40	.38	16.23
1891	.78	.83	1.63	2.28	6.60	4.29	1.75	1.50	.87	.41	.52	.32	21.79
1892	1.36	.27	.67	5.70	3.30	3.99	1.04	2.93	.32	2.46	.51	1.54	24.09
1893	.10	.71	2.41	3.45	2.01	1.63	1.14	.70		3.48	1.48	1.68	19.12
1894	.55	.12	3.08	3.48	1.15	3.80	.57	.42	.62	1.24	1.03	.72	16.78
1895	.85			2.91	3.55	5.05	.55	.95	.80	.23	2.36	.40	
1896	.66	1.11	3.43	2.51	2.69	2.62	.72	.05	2.46	Tr.	1.27	.06	17.61
1897	1.55	.05	1.36	1.80	1.05	5.32	2.05	3.11	.01	.02	.50	Tr.	16.22
1898	1.20	.15	.83	1.20	9.60	2.70	1.20	1.50	1.80	1.54	.33	1.10	23.15
1899	.91	.46	1.42	1.15	6.75	2.35	.29	.30	1.10	1.94	.14	.56	20.37
1900	.50	.31	1.11	.95	.35	3.00	2.65	1.90	2.03	.46	.50	.70	13.92
1901	.47	.99	1.71	1.68	2.83	6.78	2.83	2.75	1.35	.83	.17	.89	23.28
1902	1.53	2.30	5.63	3.80	3.35	3.57	1.11	.07	.75	.10	.01	.07	22.19
1903	.60	.90	1.70	2.55	3.36	2.16	1.25	3.56	2.90	.40	.80	.81	23.89
1904	.26	1.22	.31	.96	1.52	5.76	.40	2.35	.15				
Normal													19.41

Monthly precipitation, in inches, at Silver City, S. Dak.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1894				3.25	0.89	5.20	4.14	3.76	0.61		2.35	0.21	
1895	0.22	0.95	4.10	3.47	4.95	5.85	.48	.78	.84		.95	.20	22.80
1896						5.31	3.28	.80	3.13	0.62	1.55	.02	
1897	1.07	.33	3.21		2.31	2.56	1.42	3.10	.21	.05	1.87	.40	
1898	1.15	.97	1.56	1.22	4.03	1.68	3.16	.08	1.54				
1899	1.65	.52	2.35	.85	7.74	2.02	2.81	.73	1.06	1.95	.29	1.14	23.11
1900	.35	.65	.20				1.39	2.13	3.03	.22	.50	.07	
1901	Tr.	.69	.87	1.99	2.40	4.80	2.58	3.18	.92	.84	.34	1.20	19.85
1902	.28	Tr.	2.12	2.55	3.80	2.87	2.20	1.19	.50	.22	.33	1.20	17.26
1903	.25	.60	1.82	4.49	4.07	6.39	3.52	1.83	2.13	.45	.36	1.30	27.21
1904	1.60	2.95	.33	.41	4.32	6.48	1.37						
Normal													22.05

Monthly precipitation, in inches, at Spearfish, S. Dak.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1889	0.75	1.20	0.40	3.87	2.60	1.45	5.84	0.14	1.42	1.72	0.48	2.00	21.87
1890	2.10	.75	1.54	1.47	3.42	6.81	.20	1.66	.53	1.37	.35	.53	20.73
1891	.83	2.04	1.73	2.66	3.15	7.29	2.53	2.51	.71	1.23	.75	.90	26.32
1892	.36	.74	1.55	4.61	2.18	8.32	.73	3.09	.23	2.81	.63	1.57	26.82
1893	.49	2.15	1.45	2.21	2.91	2.13	1.43	1.97	.22	3.50	1.09	1.30	22.85
1894	1.62	.73	7.40	4.76	3.52	5.12	1.35	.33	.92	.81	1.31	.82	28.69
1895	1.50	1.45	2.42	3.91	3.95	5.48	.78						
1896										.52	.78	T.	
1897	2.25	.80	3.35	1.80	2.80	4.38	.46	1.23	0	.77	.83	.25	18.92
1898	.30	.45	1.07	1.14	3.62	1.35	1.90	.05	.60	.83	.18	.40	11.89
1899	.42	.19	2.04	1.96	3.85	2.53	2.08	.50	2.05	.84	.17	.91	17.54
1900	.66	.63	.86	2.49	1.27	3.40	2.53	2.36	1.69	1.06	.58	.20	17.73
1901	.38	.76	1.95	.97	1.86	5.22	2.94	2.06	.68	1.45	.08	.79	19.14
1902	1.31	1.93		2.31	3.50	1.08	2.41	1.44	1.38	.48	.16	1.87	
1903	.52	.85	3.98	5.56	3.08	2.28	2.99	3.73	3.88	.39	.65	1.50	29.41
1904	.85	2.13	.08	1.04	2.49	9.10	2.08	2.85	.20				
Normal													21.82

Annual precipitation, in inches, in Black Hills, South Dakota.

Year.	Rapid	Fort Meade.	Farmingdale.	Ashcroft.	Oelrichs.	Spearfish.	Silver City.
1881		15.06					
1882		19.32					
1883		27.05					
1884		22.97					
1885		13.25					
1886		13.51					
1887		18.93					
1888	22.11	20.00					
1889	17.98	18.00				21.87	

Annual precipitation, in inches, in Black Hills, South Dakota—Continued.

Year.	Rapid.	Fort Meade.	Farmingdale.	Ashcroft.	Oelrichs.	Spearfish.	Silver City.
1890	13.01	16.23	....	....	....	20.73	....
1891	16.87	21.79	....	....	22.05	26.32	....
1892	19.63	24.09	....	....	33.88	26.82	....
1893	9.58	19.12	....	13.64	16.82	22.85	....
1894	14.04	16.78	....	15.12	19.31	28.69	....
1895	16.39	....	10.82	13.17	....	....	22.80
1896	14.76	17.61	....	19.46	17.57	....	....
1897	13.36	16.62	....	10.50	....	18.92	....
1898	10.97	23.15	10.31	15.24	....	11.89	....
1899	15.64	20.37	15.54	14.41	20.65	17.54	23.11
1900	14.66	13.92	12.83	12.92	12.93	17.73	....
1901	22.59	23.28	....	10.39	24.34	19.14	19.85
1902	18.51	22.19	14.75	16.00	19.79	....	17.26
1903	21.28	23.89	17.12	12.21	18.57	29.41	27.01
Normal	16.34	19.41	13.55	13.91	20.59	21.82	22.05

RUN-OFF OF BELLE FOURCHE RIVER.

A complete record of the flow of Belle Fourche and Redwater rivers has been kept since June, 1903. The following table shows the run-off by months, also the amount available through the supply canal as planned.

The records for November and December, 1903, and January and February, 1904, are incomplete on account of formation of ice.

Estimated monthly discharge of Belle Fourche River at diversion dam.

[Drainage area, 4,265 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Rainfall.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Inches.
June	385	85	184	10,955	.04	.05	....
July	1,086	70	201	12,343	.05	.05	....
August	4,218	148	913	56,016	.21	.25	....
September	4,755	177	915	54,363	.22	.24	....
October	201	166	177	10,870	.04	.05	....
Period	....	....	....	144,547	.56	.64	....

Estimated monthly discharge of Belle Fourche River at diversion dam—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Rainfall.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Inches.
1904.							
March 10 to 31	2,082	419	1,070	46,601	.25	.20	....
April	705	334	521	30,957	.12	.14	....
May	1,903	238	532	32,684	.12	.14	1.94
June	13,814	410	2,667	158,432	.62	.70	4.68
July	671	140	338	20,770	.08	.09	.42
August	258	85	126	7,740	.03	.03	2.32
September	376	217	248	14,717	.06	.06	.23
October 1 to 15	1,174	217	345	10,241	.08	.04	2.55
Period	....	....	....	322,142	1.36	1.40	12.14

NOTE.—This station was established after the spring flood of 1903.

Estimated amount of water that could have been stored from Belle Fourche River by system as planned.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
June	385	85	184	10,936
July	1,086	70	201	12,343
August	1,635	148	657	40,301
September	1,635	177	704	41,833
October	201	166	177	10,870
Period	1,635	70	385	116,283
1904.				
March 10 to 31	1,635	419	985	43,117
April	705	334	521	30,957
May	1,635	238	521	32,019
June	1,635	410	1,235	73,373
July	671	140	338	20,770
August	258	85	126	7,740
September	376	217	248	14,717
October 1 to 15	1,174	217	345	10,241
Period	1,635	85	540	232,934

NOTE.—This station was established after the spring flood of 1903.

Considerable water will be obtained from the creeks intercepted by the system, especially from Owl Creek, which flows directly into the reservoir. No estimate can be made of this flow, as systematic ratings have not been made, and it was impossible to obtain the gage heights and length of floods on account of the absence of observers.

From the records now available it seems probable that the water supply is ample for the project, although it may need several years' records to determine the amount that may be depended on for reclamation work.

DUTY OF WATER.

The normal rainfall in this region being at least 16 inches, it is thought that the application of 2 acre-feet, or 24 inches, making a total of 40 inches, will be ample, and provision has been made for the storage of this amount plus a sufficient quantity to make up for loss from seepage, evaporation, and delivery.

Redwater canal, which waters about 4,000 acres in this locality along the east side of Redwater River, uses an average of about 40 second-feet for one hundred days. While the lower end of the canal sometimes suffers for lack of water, a large amount is wasted through the season; if the supply were regulated by storage each farm would be amply supplied.

The Spearfish ditches probably use more, but as the valley is very narrow and has more water than land much of the water returns to the creek and is used several times over; and as there are quite a number of small ditches in use it is hard to estimate the amount used. About 5,000 acres are irrigated.

Records have been kept during the past year of the water used by Redwater canal, and the exact duty will be determined from these records.

MATERIALS FOR CONSTRUCTION.

A large item of expense in this construction work is the expense of getting good stone for riprap and concrete, there being no suitable stone under the canal.

There are a few banks where gravel for concrete may be obtained, and there is also in places a formation of limestone, which consists of shattered stone suitable for concrete. The riprap or paving stone may be obtained from several localities in the Black Hills along existing railroad lines.

The following tests have been made by the ordnance department of the Army:

Quarry.	Railroad haul in miles.	Per cent of absorption.	Ultimate strength per square inch in pounds.	Specific gravity.	Remarks.
Burke	100	....	8,074	....	
Minnesela	4	10	2,192	1.92	Thin ledge.
Hay Creek No. 1	10	12	1,982	1.93	Red sandstone.
Hay Creek No. 2	10	12	1,859	1.86	
Hay Creek No. 3	10	8	4,830	1.95	
Richards	5	12	1,695	1.89	
Railroad cut	10	1.6	9,405	2.37	Good riprap; limited quantity.

Sand can be obtained at Hay Creek, along the railroad line, or at places along Belle Fourche River by wagon haul.

The shale which underlies this locality and is exposed in ledges in places might make good hard brick, if pressed and burned, and be substituted for stone for canal linings and paving.

The greatest care has been used in planning structures to keep in mind the damage made possible by the huge ice flows, which come down in the spring in large bodies from the hills. The danger from this source lasts generally only a few days on the breaking up of winter, but it is feared considerable damage might be done if a heavy dam and regulator were not built and great care not taken each year during this period.

RIGHTS OF WAY AND WATER RIGHTS.

Very little right of way will have to be bought, as most of the land in the reservoir, except the school land, is public. There is some private land above the diverting dam and at the head of the canal which must be purchased.

There are no appropriations of the water of Belle Fourche River, but several canals are diverting from Spearfish Creek and Redwater River, but as these all divert above this project much of the water is returned to the river and becomes again available, especially through the south side canal, which diverts about 15 miles below the mouth of Redwater River.

There have been numerous appropriations made of the waters of Owl, Indian, and Horse creeks, but none are used to-day except those vested rights of settlers who benefit from the overflow of the meadows along these creeks when they are in flood. This can not be depended on and is unsatisfactory.

RAPID CREEK RECONNAISSANCE.

There is probably some water available for storage from Rapid Creek, if the amount needed for lands now in cultivation below Rapid is used economically and none is wasted.

The best land available for reclamation is on the north slope of Boxelder Creek and is mostly in private ownership. To reclaim this all the spring and flood flow of Rapid and Boxelder creeks must be stored. The only known feasible site is on Boxelder Creek, near the town of Blackhawk, to reach which a diversion of Rapid Creek must be made about 6 miles above Rapid. This diversion would interfere with two power plants at Rapid that use the water for power purposes, on which account this project can not be taken up at this time. There is probably sufficient water available to reclaim 20,000 acres if the above complications were removed

LITTLE MISSOURI RECONNAISSANCE.

A reconnaissance was made of the headwaters of the Little Missouri for the discovery of possible reservoir sites, and several were found which would probably hold all the available flow.

The Alzada reservoir site, located near Alzada, Mont., was surveyed, and while quite shallow, will probably hold all the available flow at this place. Another may be located below the mouth of Thompson Creek.

Several bodies of fine land are located along this stream in the vicinity of Alzada and Capitol, Mont., and Camp Crook, S. Dak. These lands are all some distance from the railroad, in the middle of a large grazing country, and would be used principally for hay if reclaimed.

This reconnaissance will be followed by further investigations during 1905, and either lands withdrawn for reclamation in this locality or the water diverted to Belle Fourche Valley for lands there.

Estimates of capacity and work needed for Alzada reservoir.

Contour.	Area.	Capacity of section	Capacity	Earth embankment.
Feet.	*Acres.*	*Acre-feet*	*Acre-feet*	*Cubic yards.*
3,460	169	....	....	....
3,465	852	2,555	2,555	....
3,470	1,796	6,620	9,175	167,392
3,475	2,723	11,300	20,475	303,563
3,480	3,500	15,560	36,035	500,434
3,485	4,122	19,055	55,090	772,956
3,490	4,694	22,040	77,130	1,214,008
3,495	5,083	24,440	101,570	1,719,266

The embankment is to be 16 feet wide on top, with 3 to 1 inside and 2 to 1 outside slopes. A preliminary survey was made of the diverting canal from the Little Missouri, and the cost will be estimated this winter.

A rating station was established at Alzada April 1, 1904, from which the run-off may be estimated.

CHEYENNE RIVER RECONNAISSANCE.

Cheyenne River has a drainage area of about 7,350 square miles above Edgemont, S. Dak. The stream is sandy and dry for a large part of the summer, although subject to big flows in springtime from melting snow and through the summer from sudden storms.

About 40,000 acres of irrigable land are located along the river in small tracts, through the southern part of the Black Hills. The main flats are known locally as "W. G. Flat," "Harrison Flat," and "Squaw Humper Flat." There is a small tract above Edgemont for which a small canal was constructed. The project failed on account of a poor diverting dam and no provision for storing flood waters.

A reconnaissance was made in October, 1904, for storage basins. Several were found on branches of Cheyenne River. They will be surveyed if further examination shows the water supply to be sufficient.

The farmers of W. G. Flat have had several meetings and elected officers, and if sufficient storage can be found to warrant a project a water-users' association will be formed and stock subscribed for all the land before detail surveys are begun. The land has all been withdrawn.

A rating station is maintained on Cheyenne River at Edgemont, S. Dak.

OPERATIONS IN UTAH.

By George L. Swendsen.

In Utah the examinations have been directed principally to the problem of securing an additional water supply for Cache, Salt Lake, and Utah Lake valleys. In all these valleys the summer flow of all the streams is appropriated, and the problem resolves itself into one of storage and more effective control and application of the available water supply. The main streams concerned in these investigations are Bear River, with its various branches, and the streams tributary to Utah Lake. These latter drain the section south and southeast of Great Salt Lake, while Bear River drains the section north and northeast of the lake. The Utah Lake project deals with the supply of water for southern Salt Lake and Utah Lake valleys and is the foremost project in the State.

The Bear Lake project is concerned with the water supply for Cache and northern Salt Lake valleys and involves some lands in southern Idaho.

In order to get an additional water supply for Salt Lake and Utah counties it has been thought that some of the branches of Duchesne River might be diverted into these valleys, and accordingly investigations were made during this season to determine the possibilities of such a plan. This scheme is referred to as the Strawberry Valley project.

UTAH LAKE PROJECT.

The Utah Lake project involves an investigation to determine the feasibility of increasing the irrigation duty of the Utah Lake drainage basin run-off by reducing the area exposed to evaporation in Utah Lake, which now serves as a storage reservoir. It is proposed to accomplish this by cutting down and lowering the outlet through the rim of the lake bed 8 or 10 feet, to permit drawing down the water in the lake this many feet, with consequent reduction of area and saving of evaporation, which has been found to average 5 feet in depth each year over the entire surface exposed. The irrigable land tributary to the proposed project is largely in excess of the water supply possible to develop from this source. The investigations indicate the feasibility of the undertaking, but before final conclusions and decisions can be made it will be necessary to have an adjudication of all water rights within the drainage basin. It is expected that this work will be taken up at once and pushed to early completion by the proper State officials, to whom it has been referred.

A general outline of the project is given in the First Annual Report of the Reclamation Service, pages 279–282, and a more detailed outline, together with maps, hydrographic conditions, estimates, etc., is given in the Second Annual Report, pages 451–475.

WATER SUPPLY.

Utah Lake, which has an area of 93,000 acres when the maximum allowable elevation of 4,486.66 feet is reached and a depth of only 13 feet, and an area of 17,500 acres when the water is drawn down to within a foot of the bottom, offers a unique storage problem in many particulars—a problem further complicated by the fact that a large part of the water supply comes from springs in the body of the lake and from seepage on the shore, and must be referred to as an unmeasured supply. The supply of water that can be measured comes from 33 streams flowing into the lake from its eastern shore and from the direct rainfall on the lake surface. A detailed record of these 33 streams, August, 1903, to August, 1904, is given in the table on page 486, indicating a total measured supply of 354,882 acre-feet for the year. Provo River and Spanish Fork are the largest of these streams. The normal summer flow is all appropriated for irrigation of the lands in Utah County. The rights on Spanish Fork have already been adjudicated and a suit is pending for the settlement of the rights on the Provo.

The first table on page 498 and data relating to rainfall, lake surface fluctuations, evaporation, and water utilized are used in the preparation of the table on pages 498–500, which gives the conditions of the lake from August, 1901, to August, 1904. This table shows that the average water supply to the lake for the three years was 524,300 acre-feet. Two of the years used in the table are years of a very low water supply, while the last of the years is thought to be one of average run-off, so that the result should be conservative.

The status of the records is such that the tables can not be extended definitely over a longer period. Prior to 1901 a large amount of water was wasted through Jordan River in efforts to carry out the agreement that the lake should not rise above the "compromise" level and flood certain lands along it.

The record of the commission having this matter in charge shows that the matter was very carefully guarded, and at any approach of the lake surface to compromise level the gates of the storage dam were opened.

Notwithstanding the diligence in this matter the lake level has risen to compromise level in eleven of the past fifteen years, and in eight of these eleven years has risen 1 to 3 feet above compromise, though the storage gates in the Jordan were entirely open and a discharge of 500 to 700 second-feet was flowing out of the reservoir during all the winter and spring months. Unfortunately this loss was not measured, but when the lake rises to compromise point the river flows very near to 500 second-feet, and, of course, more as the lake gets higher. By means of this factor it is estimated that the waste in high-water years, such as 1893, 1897, 1898, and 1899, reached as much as 200,000 acre-feet per year. If provision were made to store the water supply in years of high water, there is no doubt that the available supply from the lake could be much greater than the records of the last three years indicate.

In 1888 and 1889 the water supply was low. In 1889 the lake level was about 1 foot lower than at present and within one-half foot of the lowest stage known. This was followed by eleven years of large supply, and it therefore seems hardly probable that the present low cycle will be continuous. However, with an average annual supply of 524,300 acre-feet, as a basis, and beginning with the lake at its present level, 4,483 feet, the table on pages 500–502 has been prepared to show the result of drawing a definite volume (229,500 acre-feet) each year for irrigation. The bed of the lake is at an elevation of about 4,473 feet, and the table indicates that surface of the water would be at an elevation of 4,474.36 feet at the end of the fifth year, and a further computation shows that the lake would maintain itself with that draft and supply from year to year thereafter. If one of the five years should be characterized by unusually large supply, the conditions would be very much changed.

In the tables on pages 498–502 such allowances as seemed proper have been made for losses due to increased evaporation on the shallow portions of the lake and to partial loss of rainfall and seepage on the exposed lake bed as the lake recedes. In the case of the lower levels the supply indicated in the table on page 498 has been reduced 75 per cent in the summer months, while the unmeasured or underground supply is considered as distributed uniformly over the lake bed and that portion of the surface exposed is in all cases eliminated. It seems, therefore, that the table on pages 500–502 should be an entirely safe basis for a definite outline of the project, and also that even a greater available supply may with fair degree of certainty be expected. It is believed, therefore, that the works should be designed to deliver 300,000 acre-feet a year.

While the seepage or unmeasured supply to the lake may be looked upon as a rather dangerous factor to depend upon as a water supply, investigations in the last season have developed some of its sources with considerable certainty. In the northwestern portion of the lake eight large springs have been found, some of which are 80 feet in depth and cover an area of 2 acres each. Others are smaller, but have sufficient flow to prevent the deposit of silt. To what extent such springs may be distributed over the other portions of the lake was not determined, but they indicate that the supply of water from the bed of the lake is a rather definite and dependable quantity. It should be said in passing that a 2-inch pipe driven near these springs brings a flow of water to the surface—in some cases hot water, in others cold, and in two cases with pressure sufficient to force the water 12 to 15 feet above the surface.

Therefore, instead of the seepage or subterranean supply to the lake being widely distributed it will probably be found to be more or less concentrated, and as such it will be a definite and available resource.

During this season complete storage of all the flood waters was effected, and according to the detailed records of the water commissioner 120,000 acre-feet have been utilized in the season of one hundred and sixty-five days. Detailed examination of the lands shows that this was used on a total area of 45,684 acres, indicating a depth of 2.63 feet on the land and a duty of 111 acres per second-foot, measured at the heads of the several canals. The distributing system for this area is shown in Pl. LV of the Second Annual Report of the Reclamation Service, page 456, and the court adjudication of the claims is tabulated on page 457 of the same report.

The detailed examination of the lands was made by Thomas P. Page; his report covered all details relating to the condition of the land, so far as water supply is concerned, only 4,000 acres being reported scantily irrigated.

The past three seasons, when the entire supply of water has been pumped from the lake, have brought the matter of more careful use of water prominently before the irrigators, and their methods are rapidly improving.

In order to make the canal systems effective and dependable, considerable reconstruction will be necessary, and through the canyon portion at least all the 4 existing canals must necessarily be reconstructed throughout if the scheme to utilize the entire lake supply is perfected.

From observations over the area, it seems that a depth of 3 feet should be a liberal allowance for the season's supply on whatever land may be developed, and that the lake should furnish water for 70,000 to 75,000 acres of land, based on the foregoing water-supply data. Of course, the actual area irrigated may depend upon the location of the lands that may be added to the irrigated area, but it is believed that the estimate is a safe one.

The table following gives the discharge, in acre-feet, of the measurable streams east of Utah Lake; they are numbered consecutively from north to south.

Discharge, in acre-feet, of measurable streams flowing into Utah Lake, August 1, 1903, to July 31, 1904.

Stream.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.
1	17	16	17	16	17	14	9	9	11	22	373	......
2	595	576	595	576	595	644	676	723	765	1,231	918	552
3	57	55	57	55	57	57	53	57	51	22	30	......
4	95	91	94	91	94	93	85	91	100	182	199	167
5	69	67	69	67	69	80	92	98	93	84	99	62
6	12	11	12	11	12	20	32	34	31	21	26	19
7	4	4	4	4	4	8	14	15	18	39	57	......
8	31	30	31	30	31	72	127	136	121	55	752	62
9	......	......	......	......	......	......	......	......	7	54	......	......
10	44	43	44	43	44	33	14	15	32	154	174	248
11	83	80	83	80	83	80	71	76	97	258	177	143
12	14	13	14	13	14	24	38	40	43	74	511	167
13	......	......	......	......	......	......	......	......	......	......	22	......
14	10	10	10	10	10	24	46	50	65	221	548	105
15	502	485	502	485	502	561	626	670	649	679	1,452	518
16	32	31	32	31	32	23	6	6	56	520	647	304
17	60	58	60	58	60	61	58	62	54	3	20	68
18	20	19	20	19	20	20	20	21	31	133	466	310
19	3	3	3	3	3	5	7	7	8	18	21	31
20	37	36	37	36	37	34	27	29	27	19	21	31
21	1,513	1,464	1,513	1,464	1,513	1,539	1,483	1,585	1,534	1,587	1,536	1,587
22	41	40	41	40	41	67	108	115	102	14	......	......
23	......	......	......	4,340	10,476	9,546	14,770	18,102	20,602	48,434	40,740	......
24	665	643	665	643	665	461	318	340	329	410	345	279
25	393	380	393	380	393	302	103	110	107	151	178	184
26	129	125	129	125	129	137	143	152	148	115	184	217
27	16	15	15	15	16	16	16	17	17	28	35	31
28	77	72	74	72	74	50	......	......	......	......	7	31
29	4,393	4,251	4,393	4,251	4,393	4,475	4,408	4,712	4,560	4,836	5,474	5,382
30	1,668	1,615	1,668	1,615	1,668	1,678	1,593	1,703	1,648	1,954	2,358	2,151
31	166	161	166	161	166	248	118	180	3,670	5,293	1,190	31
32	......	......	2	1,270	2,244	2,522	1,134	5,176	9,738	11,730	......	......
33	......	......	......	......	......	......	......	......	286	656	480	496
Total	10,746	10,394	10,713	16,001	23,462	22,894	29,495	34,931	45,000	78,997	59,040	13,176

The following tables show the fluctuation of the lake surface from 1904 to 1904:

Elevation of Utah Lake and water received August, 1901, to August, 1904.

Month.	Lake surface.		Water supply.		
	Mean elevation.	Area.	Measured.	Unmeasured.	Total.
1901.	*Feet.*	*Acres.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
August	4,484.09	85,000	6,140	33,420	39,560
September	83.68	83,800	3,270	8,730	12,000
October	83.44	83,000	4,840	26,160	31,000
November	83.52	83,200	6,170	23,950	30,120
December	83.76	84,000	7,170	34,330	41,500

Elevation of Utah Lake and water received August, 1902, to August, 1904—Continued.

Month.	Lake surface.		Water supply.		
	Mean elevation.	Area.	Measured.	Unmeasured.	Total.
1902.	*Feet.*	*Acres.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
January	84.09	85,000	2,580	34,040	39,620
February	84.45	85,900	8,320	41,550	49,870
March	84.70	86,700	9,700	26,000	35,700
April	84.76	86,800	16,000	26,300	42,300
May	84.72	86,700	2,700	55,750	58,450
June	84.52	86,100	710	47,460	48,170
July	84.05	84,700	800	18,740	19,540
Total			68,400	379,430	447,830
1902.					
August	4,483.62	83,400	1,500	56,540	58,040
September	83.09	82,000	180	3,250	3,430
October	82.54	80,400	4,940	38,430	43,370
November	82.45	80,200	11,170	9,510	20,680
December	82.72	81,000	9,220	39,100	48,320
1903.					
January	83.14	82,200	19,270	22,810	42,080
February	82.58	83,400	4,920	37,000	41,920
March	84.10	85,000	13,350	72,470	85,820
April	84.48	86,600	3,770	34,660	38,430
May	84.45	86,000	20,050	42,870	62,920
June	84.26	85,200	2,130	53,620	55,750
July	83.64	83,600	2,830	17,490	20,320
Total			93,330	427,750	521,080
1903.					
August	4,482.81	81,200	13,790	2,240	16,030
September	82.27	79,800	15,570	12,740	28,310
October	82.06	79,100	14,700	8,290	22,990
November	82.10	79,100	24,180	7,420	31,600
December	82.31	79,800	26,920	3,060	29,980
1904.					
January	82.65	80,800	35,320	10,780	46,100
February	83.17	82,200	46,140	14,590	60,730
March	83.85	84,100	62,560	29,000	91,560
April	84.48	85,800	56,620	13,610	70,230
May	84.83	87,000	94,840	10,090	104,930
June	84.97	87,500	62,210	18,040	80,250
July	84.50	86,100	18,290	3,010	21,300
Total			471,140	132,870	604,010

Elevation of Utah Lake and water supply, August, 1902, to August, 1905—Continued.

SUMMARY.

	Acre-feet.
First year	447,830
Second year	521,080
Third year	604,010
Average for three years	524,300

Average elevation and water supply of Utah Lake for 3 years, based on average supply of 524,300.

FIRST YEAR.

First day of—	Lake surface.		Water supply.		Utilized.
	Elevation.	Area.	Available.	Evaporation.	
	Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
October	4,483.00	81,700	31,710	26,310	....
November	83.06	82,000	27,470	17,060	....
December	83.18	82,200	39,750	10,280	....
January	83.52	83,200	42,070	10,400	....
February	83.[illegible]	84,300	50,220	14,080	....
March	84.32	85,500	70,070	24,970	....
April	84.84	87,000	50,040	33,580	....
May	85.04	87,700	75,350	56,390	46,500
June	84.72	86,700	60,940	63,550	45,000
July	84.18	85,000	20,270	66,640	46,500
August	83.07	82,000	37,490	57,400	46,500
September	82.24	79,500	14,060	44,920	45,000
Total			519,440	425,580	229,500

SECOND YEAR.

First day of—	Elevation.	Area.	Available.	Evaporation.	Utilized.
October	4,481.27	76,200	31,210	24,540	....
November	81.35	76,500	27,020	15,910	....
December	81.76	77,000	39,430	9,630	....
January	81.87	78,[illegible]	41,480	9,790	....
February	82.28	79,600	49,620	13,290	....
March	82.73	81,000	69,060	23,650	....
April	83.28	82,500	49,550	31,850	....
May	83.50	83,000	74,840	53,370	46,500
June	83.12	82,200	60,560	60,250	45,000
July	82.65	80,700	20,130	63,270	46,500
August	81.54	77,000	37,230	53,900	46,500
September	80.67	73,700	13,760	41,640	45,000
Total			513,900	401,090	229,500

Average elevation and water supply of Utah Lake for five years, etc.—Continued.

THIRD YEAR.

First day of—	Lake surface.		Water supply.		Utilized.
	Elevation.	Area.	Available.	Evaporation.	
	Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
October	4,479.65	68,000	30,460	21,900	....
November	79.77	68,600	26,360	14,270	....
December	79.95	69,600	38,990	8,700	....
January	80.38	72,200	40,760	9,020	....
February	80.82	74,500	48,960	12,440	....
March	81.30	76,300	68,000	22,280	....
April	81.89	78,400	49,110	30,260	....
May	82.13	79,200	74,420	50,930	46,500
June	81.83	78,200	60,210	57,320	45,000
July	81.30	76,300	19,980	59,820	46,500
August	80.10	70,500	36,890	49,350	46,500
September	79.26	66,000	12,050	37,290	45,000
Total	....	....	506,190	373,580	229,500

FOURTH YEAR.

First day of—	Elevation.	Area.	Available.	Evaporation.	Utilized.
October	4,478.13	59,800	29,710	19,260	....
November	78.32	61,000	25,740	12,690	....
December	78.52	62,000	38,540	7,750	....
January	79.02	65,000	39,910	8,120	....
February	79.49	67,200	48,020	11,220	....
March	80.03	70,000	66,570	20,440	....
April	80.68	73,700	48,600	28,450	....
May	80.95	75,000	73,960	48,230	46,500
June	80.65	73,600	59,820	53,950	45,000
July	80.12	70,600	19,780	55,350	46,500
August	78.90	64,200	29,470	44,940	46,500
September	77.89	58,000	9,030	32,770	45,000
Total			489,150	343,170	229,500

Average elevation and water supply of Utah Lake for five years, etc.—Continued.

FIFTH YEAR.

First day of—	Lake surface.		Water supply.		Utilized.
	Elevation.	Area.	Available.	Evaporation.	
	Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
October	4,476.52	43,000	28,180	13,850	....
November	76.84	46,600	24,540	9,690	....
December	77.15	50,000	37,850	6,250	....
January	77.74	56,300	38,880	7,040	....
February	78.29	60,700	47,180	10,140	....
March	78.89	64,000	65,210	18,690	....
April	79.59	67,700	47,950	26,130	....
May	79.90	69,300	73,340	44,560	46,500
June	79.64	68,000	59,340	49,840	45,000
July	79.12	65,400	16,060	51,270	46,500
August	77.79	57,000	14,900	39,900	46,500
September	76.32	41,000	8,150	23,170	45,000
September 30	74.36	21,000	....	....	....
Total	....	....	461,580	300,530	229,500

LAKE INVESTIGATIONS.[a]

From 70,000 to 75,000 acres are to be irrigated, to accomplish which it may be necessary to draw upon the lake to a lower level than is now possible. That is to say, a plan must be devised whereby the 500,000 acre-feet of water in the lake below the level of the present outlet channel may be rendered available. Some suggestions relating to the problem were expressed in the Second Annual Report of the Reclamation Service, pages 459–465, and during the field season of 1904 the matter received detailed attention by a field party in charge of A. H. Horton, engineer. The examinations of this party also covered the sections of the lake that would be affected if its area were reduced by cutting off portions of it by dikes in order to reduce the surface subject to evaporation.

The northern end of the lake, through which an outlet channel would necessarily be built, was well covered with borings, and in addition the narrow neck at the mouth of Provo Bay and the section across the northern end of Goshen Bay were examined for a foundation for cut-off dikes. The borings were made from a flatboat upon which was mounted a tripod, a pump, and other equipments necessary for making washed borings. The equipment was sufficient to explore to a depth of 108 feet.

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[a] From report by A. H. Horton.

The material in the lake bottom away from the shores was found to be a very fine, smooth, slick clay, light colored on top, and changing in most cases to a bluish color under the surface. Nearer the shores the clay is stiffer and is mixed with sand to some extent, but well away from the shore, in the deeper water, the clay is very soft. In some instances one man's weight was sufficient to force the 2½-inch casing down 20 feet, and in most cases the weight of four or five men was sufficient to force the casing down to any desired depth.

It is not believed that this material will stand in embankment when deposited wet in the water, and it is thought that a channel would not preserve its shape should one be dug in the lake bed. When deposited in embankment it will doubtless spread out greatly while it is being placed, and in time will probably flatten out to its original shape. When the material is placed on shore and allowed to dry out the clay becomes hard and firm and will stand at almost any slope.

Along the north and east shores the material is mostly sand, extending in most cases to a depth exceeding any probable channel construction. In some cases quicksand was encountered and the casing sank rapidly by its own weight. In general, this sand extends some distance from shore and gradually merges into soft clay. The material along the western shore, as far south as the channel would extend, consists of sandy clay 2 or 3 feet thick, underlain by strata of hardpan or cemented sand, gravel, and bowlders. These strata of hard material have a rather steep slope toward the body of the lake.

PROVO BAY CUT-OFF.

The mouth of Provo Bay is very narrow and is divided into three channels, varying in width from 50 to 900 feet, with a maximum depth of 7 feet. The total width of waterway with the lake at the 4,484-foot level is 1,160 feet; the material of the bed is a very compact clay which would readily support a cut-off embankment.

The neck of land separating the bay from the main lake lies at an elevation of 4,486.66 feet, or compromise level, and would be flooded if the lake were raised above compromise. The area of Provo Bay is 5,000 acres.

GOSHEN BAY CUT-OFF.

At the south end is Goshen Bay, which has an area of 30,000 acres. It has been suggested that this area might be segregated from the main lake, thus further reducing the evaporating surface. Examination shows the distance across the lake at that point to be 29,000 feet and the material of the lake bed the characteristic soft clay, with rock for a short distance on both shores. The maximum depth of water is about 9½ feet.

LAKE SPRINGS.

While checking the soundings in the northwestern section of the lake 8 deep holes were found, varying in depth from 10 to 90 feet and in area from 100 square feet to 2.5 acres. The holes occur in two groups, 3 are near the shore at the north end of the lake, and the other 5, including all the larger ones, are in the northwest section, about one-fourth mile from shore. All but one of these holes give evidence that water, which in most cases is warm, is flowing from them. They show conclusively that there is considerable water coming into the lake from underground sources.

Several flowing wells were found by the boring party at depths of 80 to 100 feet; several were along the eastern shore, but the largest ones were in the vicinity of the springs described above.

CONCLUSIONS.

In consideration of these conditions the feasibility of maintaining the channel through the lake has been seriously questioned by the board of engineers, and it has been decided that such a channel would not have sufficient stability at the entrance to afford a grade for velocity head. In none of the routes considered has the problem of maintaining a channel in the soft clay of the lake bed been satisfactorily solved. The use of one of the large springs as an intake basin for an outlet channel was suggested by a board of engineers on September 29, and detailed examinations relating thereto are now in progress. One of the largest springs is only 1,500 feet from the northwestern shore, thus reducing the lake channel to a minimum. The maintenance of a wide channel from this spring into the main body of the lake is believed to be feasible. If the detailed surveys show such a plan to be feasible the problem of drawing down the lake will be greatly simplified.

The examinations relating to the reduction of the lake area exposed to evaporation indicate that it might be feasible to construct a dike across the outlet of Provo Bay, but that the materials across Goshen Bay would not support a dike. These considerations are, however, of doubtful utility. The water saved can not possibly pay for the expenditure necessary, and for the present, at least, such a procedure should not be recommended.

If the storage capacity of the lake is increased, as suggested in the water-supply discussion, the lands that will be flooded are confined principally to the eastern and southern shores, which, in most cases, are natural meadows and in many cases swamps, useful only for pastures in the dry portions of the year. The most valuable lands that would be flooded are probably those around Provo Bay, and should the damages resulting be excessive the segregation of the bay from the main lake by a dike might be considered. Many of the claims on the lake shore extend beyond the meander lines of the Federal survey, and the actual acreage of land entitled to claims for damage would be considerably less than the apparent area. A plane-table survey of the entire lake shore that would be flooded has been made, with 1-foot contour intervals, thus making available all details relative to this matter.

CANAL SYSTEMS.

From the lake the channel would follow the general course of Jordan River to the head of the existing canal systems outlined on Pl. LV of the Second Annual Report. In this section of the channel a large amount of excavation would be necessary, but the material is of such a character as to afford no difficulties. The excavation could probably all be made by steam shovels or dredges, borings developing the fact that the greater part of the material is clay, with bowlders and gravel in the extreme northern section. The latter material has been successfully handled by steam shovels in railway construction through the Jordan Canyon.

Plane-table sheets are completed, exhibiting the section from the lake through the Jordan River narrows and well to the north in Jordan Valley. These sheets show that the canal systems through the Jordan narrows are very faulty in alignment and that the improvement of the old systems through that section would probably not be advisable. Examination of the canyon portion of these canals, with their wooden flumes and very unstable banks, explains fully the difficulties attending their operation and the numerous breaks and slides that occur. The examination, therefore, has been conducted with the notion of displacing the four canyon channels by one well-constructed channel on the most direct route available. Examination shows that this location could best follow the general course of the Utah and Salt Lake canal as far as the Jordan narrows power house, from which point the water could be distributed to the canal systems, and in the vicinity of which the necessary pumping would be done.

By such an arrangement the pumping machinery could be of the simplest kind, probably without electrical installation for power.

The existing canals from this point throughout the irrigated section are well constructed, though in some cases the alignment is faulty and the subdivision system needs improvement. A portion of the surplus water developed will doubtless be utilized through these canal systems, and in their extension and enlargement such defects will be readily eliminated. It is not considered advisable to abolish these systems in order to reduce the entire system to more perfect form. The financial feature of such an undertaking would make it difficult, and the advantage gained would not be comparable with the expense.

Should the water users' association acquire these systems they could be worked into the general scheme to advantage, both in supplying the farms now cultivated and by means of enlargements and extensions in reaching lands not now irrigated.

A plane-table survey, calculated to form a basis for designing such improvements and new structures as may seem best adapted to the requirements of the conditions, is in progress and well advanced. This survey, which is in charge of W. T. Turner, topographer, has already been extended over the lands surrounding the reservoir and well down into those of the Jordan Valley. It is being carefully made, with contour intervals of 1 to 5 feet, according to existing conditions, and generally on a scale of 400 feet to 1 inch.

As there are no physical difficulties worthy of note to be encountered in the extension and enlargement of these canal systems, the extent and direction of the improvements will depend largely upon the attitude of the landowners and the arrangements that may be possible with the existing companies.

LANDS BENEFITED.

A large part of the section to be benefited would comprise lands under existing canals, but the extension of these would bring arid lands into use. This matter is outlined to considerable extent in the Second Annual Report of the Reclamation Service, page 466, and further reconnaissance substantiates the statements there made as to the acreage and value of the lands.

In pumping to the higher levels it is found that power will have to be secured from a distance, a fact which will increase the cost. While much of the land to be supplied by this high pumping is first class in every particular, and would thus be very valuable if a water supply could be secured, it will probably be more profitable to extend the gravity systems to available lands, accomplishing the reclamation at a reasonable cost. This will probably be the outcome of the matter as far as lands are available under a gravity supply, and should the area in Tooele County be found desirable for reclamation, the pumping to high levels would probably be of questionable utility.

Very much will depend upon the action of the water users' association which is now being formed. The canal systems are the key to the situation, and with the settlement of their status plans for extensions and further construction can be made in a very short time.

About 50,000 acres are under the existing systems, and about 20,000 or 25,000 more would be secured, as suggested above, by extensions of existing systems or by pumping to the higher levels.

WATER USERS' ASSOCIATION.

The organization of a water users' association has been undertaken by the State arid land reclamation fund commission. Speaking of the progress made, Chairman A. F. Doremus, of the commission, says:

> Considerable educational work has been done among the water users residing in the different localities embraced in the combined Utah Lake and Bear Lake irrigation project, comprising the counties of Utah, Salt Lake, Davis, Weber, and Cache, in Utah, and part of the county of Oneida, in Idaho. As chairman of the commission, I have, in company with Mr. F. S. Richards, its legal counsel, held meetings with the water users in the different localities where they reside, and recently in Salt Lake City. At the latter representatives were present from all parts of the proposed irrigation district. After fully considering the advisability of organizing a water users' association it was unanimously decided to do so, and a committee was appointed to act with the commission in preparing articles of incorporation.
>
> Articles of association were thus prepared and are now being circulated throughout the entire district for the signature of those who desire to become shareholders in the association. We have every reason to believe that the articles will receive the approval of the people and that an organization will soon be effected.

In relation to the prospects for a satisfactory organization and the attitude of the prospective water users, it may be said that in the meetings of farmers held to consider the subject extreme liberality and confidence has been apparent.

REPORT OF CONSULTING ENGINEERS.

In September, 1904, a board of consulting engineers, composed of H. N. Savage, George Y. Wisner, and W. H. Sanders, made an inspection of the surveys, maps, computations, diagrams, and samples of material prepared under the direction of George L. Swendsen, district engineer, in connection with the Utah Lake project.

The board also visited Utah Lake and personally inspected the ground and materials to be moved, and considered the difficulties to be overcome in constructing and maintaining the channels through the bed of the lake. It found from the statements and statistics submitted by the district engineer that the irrigation duty in Utah Lake, with its present water supply and storage as limited, physically and by "compromise" is exhausted. It added, however, that in its opinion the duty of the water supply available to Utah Lake, as shown by the exhibits, can be substantially augmented, both by increasing the storage depth in the lake and by constructing a deeper outlet canal from the lake to draw upon the water below the present outlet and by reducing the area exposed to evaporation.

It has been suggested that the lake area exposed to evaporation be reduced by diking off Provo Bay and the south portion of the lake. Investigations indicate that the material in the bed of the lake is of such character that this plan is not feasible.

Three locations were proposed to the board for an outlet canal to draw the water from the lake, one on each side and the third through the center, all discharging into a main outlet canal down the valley of Jordan River. The board found that it would be very expensive to maintain a canal at any of these three locations. Investigations have disclosed several large depressions, evidently springs, near the northwest portion of the lake, providing a satisfactory intake basin, which, in the opinion of the board, is essential for the operation and maintenance of an outlet channel. It is the opinion of the board that a wide channel can be dredged from the springs back into the lake and maintained. The location of these springs, only about 1,500 feet from the northwest shore, greatly reduces the length of outlet channel.

The board recommended an immediate survey to determine the area of tillable and pasture lands which would be flooded by storing water in the lake 2½ feet above the "compromise" level; also that borings be made to determine the nature of material to be encountered between the springs and shore line and along that portion of the canal bordering the lake.

STRAWBERRY VALLEY PROJECT.[a]

GENERAL OUTLINE.

Southeast and south of Utah Lake in the higher sections of Utah Lake Valley are some very choice lands, a large portion of which are entirely without water, while the remainder gets a flood-water supply that permits a scant and unprofitable growth of farm products. For several years the irrigation of these lands by storage has been under consideration. Indeed, some water has been profitably stored, but neither Spanish Fork nor Provo River affords profitable storage facilities, and to reclaim these lands completely the attention of the farmers interested has been attracted to some of the unappropriated water of the branches of Duchesne River in the Uinta Mountains. The nearest of these streams is the Strawberry, one of the branches of which heads on the divide between the Duchesne and the Spanish Fork drainage. The Strawberry is normally a small mountain stream with a flow of about 27 second-feet, but in spring flood it reaches as high as 470 second-feet. Near its upper stretches, at an elevation of about 7,500 feet, it passes through a very large flat valley of several thousand acres area, at the lower end of which it enters a narrow canyon. These conditions offer a very fine site for a storage reservoir of such dimensions that two very inexpensive dams would store 300,000 acre-feet of water. The second dam is necessary because of a second and smaller valley drained by Indian Creek, which passes through a second canyon and joins the Strawberry below the main Strawberry Valley Canyon. The divide between these two valleys is low and the second dam is necessary. Indian Creek Valley would be flooded if the large valley were utilized to its utmost capacity. However, either basin could be used on a comparatively small scale without the other. The storage facilities, therefore, are of the best, but in order to utilize the water in Utah Lake Valley a tunnel 20,000 feet long would be necessary. Such a tunnel would discharge the water of the reservoir into Diamond Creek, a branch of Spanish Fork. (See Pl. LV.)

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[a] From report by E. F. Tabor.

The tunnel makes the project very expensive, and after preliminary examinations were made and the water supply of the Strawberry available for storage was found to be only about 50,000 acre-feet per year, it was deemed advisable to investigate the feasibility of increasing this supply by diverting some of the more easterly branches of the Duchesne to the reservoir site. Up to this time the investigations had been made in cooperation with the farmers by the State land board with a portion of the Utah land-grant reservoir fund. The examinations were in charge of A. F. Doremus, State engineer.

When the larger scheme was conceived it was brought to the attention of the arid land reclamation fund commission, by whom it was recommended to the Secretary of the Interior early in 1904 as a possible feasible Federal project. Hydrographic investigations were at once ordered, and a very thorough record was secured of the flow of all the streams that could be concerned in the project. The results are tabulated below. As soon as the weather would permit a reconnaisance party was dispatched to the locality, and by the end of September the entire situation had been examined and a preliminary report prepared by E. F. Tabor, assistant engineer, who had charge of the reconnaisance.

The purpose of the survey was to determine the feasibility of reenforcing the water supply of the Strawberry Valley by diverting into it the waters of Duchesne River and some of its tributaries, with the intention of using the combined water on lands west of the Wasatch Range in Utah and Salt Lake counties.

SURVEYS FOR TUNNEL AND CANAL LINES.

Surveys were begun June 20 from Strawberry Valley and continued eastward to Duchesne River. The method adopted was to run a compass-stadia line approximately on grade contour, carrying also the elevation with a mountain transit, and checking the elevation by comparison with a line of levels carried on at the same time with wye level. Transverse slopes were read at each station occupied and notes of material and topography kept.

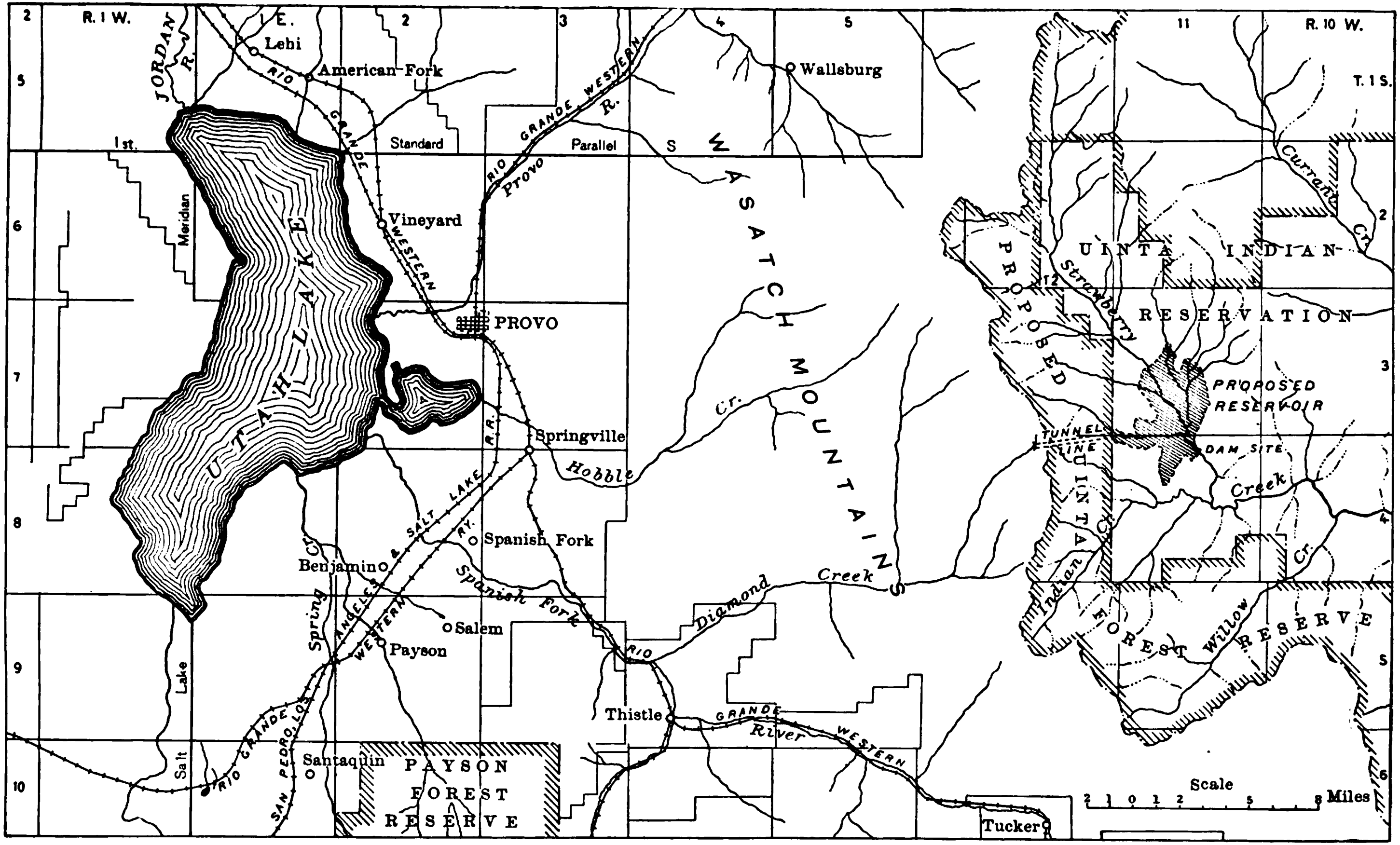
The line runs entirely through sedimentary rocks, varying from sandstone and shale to conglomerate. Near Strawberry Valley the strata lie nearly horizontal, while farther north and east the dip is south, reaching 40° to 45° in places.

The grade contour line is exceedingly tortuous, for while the distance from the Strawberry dam site to the East Fork of Lake Fork is 50 miles in an air line, the surveyed line was about 190 miles in length and the lines on which estimates were based were 157 and 82 miles. Currant Creek, North Fork of Duchesne, and Rock Creek in particular, run in deep canyons, so that the grade contour approaches each closely, although from 500 to 700 feet above the stream. To head these requires a line nearly parallel with the stream and from 6 to 10 miles long, with a similar distance on the other side before the immediate canyon of the stream may be left.

The total rise in the surveyed line allowed for grade was 180 feet, but in estimating quantities the upper end of the canal at East Fork of Lake Fork was assumed to be high enough to give a total fall of 411 feet, while the length was estimated to be the same as the surveyed line. Probably the additional grade would lengthen the line 5 miles. The increase of grade was limited by the position of a lake on the West Fork of Lake Fork, which would form a small storage basin. Any great increase in altitude of the line as a whole would throw it onto rougher ground at the heading of all the streams.

East of Currant Creek a number of tunnel lines were run as work progressed as the obviously best means of avoiding long detours, and others have been included in the estimate but not traced on the ground as necessary to avoid vertical cliffs, rock slides, or slopes too broken or steep to allow of canal construction and maintenance. The total tunnel shown would, no doubt, be increased on the location of the line.

The great length of line both in heavy canal work and in tunnel makes several long tunnels appear preferable to the surveyed lines, notably from the head of Rock Creek to North Fork of Duchesne River, from West Fork to Currant Creek, and thence to the reservoir at its northern extremity. If the project is ever seriously considered



GENERAL MAP OF PROPOSED STRAWBERRY VALLEY PROJECT, UTAH.

these tunnels should be adopted, both on account of their cheaper construction and as being the only location that would assure safety in operation. The rocks that constantly fall from the cliffs and occasional snowslides would make the operation of an open canal difficult if not impossible. Further, the material below 1 to 3 feet from the surface is all sandstone, shale, or conglomerate, and mostly on such slopes that excavated material would be lost and the canal would not hold water without some form of lining.

The line ranges between 7,560 and 7,970 feet in elevation, and is overhung by cliffs and steep slopes reaching in some cases 2,500 feet above grade in three-fourths of a mile, while the winter temperature due to these altitudes would cause trouble with the ice.

The water supply has been gaged during the past flood season, and taking the maximum flow of each stream as the measure of capacity of canal required the following capacities were used for estimating quantities:

Water supply for Strawberry reservoirs.

Section.	Stream.	Discharge.	Grade.	Velocity.
		Sec.-ft.		*Sec.-ft.*
A	East Fork of Lake Fork	140	0.001	3.46
B	West Fork of Lake Fork	540	.0006	3.75
C	Rock Creek	1,280	.0005	4.70
D	North Fork Duchesne	1,790	.00045	4.67
E	West Fork Duchesne	1,980	.0004	4.73
F	Currant Creek	2,172	.00037	4.83

The water section is, in each case, all in cut; slopes below water line, 1½ to 1; 6-foot berm, 1 foot above water, on upper side; and ½ and 1 slope above berm. On this basis is made the following estimate:

Estimate of excavation necessary for Strawberry Valley project.

Section.	Canal.			Tunnel.		
	Length.	Excavation per mile.	Total excavation	Length.	Excavation per mile.	Total excavation.
	Miles.	*Cubic yards.*	*Cubic yards.*	*Miles.*	*Cubic yards.*	*Cubic yards.*
A	11.44	34,000	388,960	2.18	10,600	23,108
B	21.47	140,000	3,005,800	3.75	32,000	120,000
C	31.42	285,000	8,954,700	9.96	64,000	637,440
D	7.57	515,000	3,898,550	5.91	80,000	472,800
E	30.40	521,000	15,838,400	5.80	80,000	464,000
F	21.88	528,000	11.552,640	5.58	80,000	446,400
	124.18	....	43,639,050	33.18	....	2,163,748

Alternative estimate in Strawberry Valley project (sections C, E, and F all in tunnel).

Section.	Canal.			Tunnel.		
	Length.	Excavation per mile.	Total excavation.	Length.	Excavation per mile.	Total excavation.
	Miles.	*Cubic yards.*	*Cubic yards.*	*Miles.*	*Cubic yards.*	*Cubic yards.*
A	11.44	34,000	388,960	2.18	10,600	23,108
B	2.47	140,000	3,005,800	3.75	32,000	120,000
C				11.74	38,000	446,120
D	7.57	515,000	3,898,550	5.91	80,000	472,800
E				9.09	63,000	572,670
F				7.95	63,000	500,850
	41.48	....	7,293,310	40.62	....	2,135,548

On an average about 75 per cent of all canal excavation would be classed as solid rock. These figures are so large compared with the run-off, about 400,000 acre-feet, that it seems not worth while to consider further particulars.

Strawberry Valley may be utilized for the storage of only the natural run-off by building one dam to a height of 30 to 35 feet, and a length of about 300 feet, and 1 mile of cheap canal to divert Little Strawberry or Indian Creek into the large basin. The outlet tunnel of 20,000 feet length toward the lands in question would be the serious part of the project and might prohibit construction until the demand for and value of water becomes greater.

As a small unit in a Colorado River system of reservoirs the dam and canal would be the only expense necessary to store 40,000 to 50,000 acre-feet available for use anywhere on the stream as far as Yuma.

There are opportunities to utilize locally part of the flow of the Duchesne on lands along its valley at elevations below 6,900 feet, and on the bench between Lake Fork and Rock Creek. The water of the former stream could be used at a moderate cost, but any diversion of Rock Creek or of Duchesne River beyond their immediate valleys would be very expensive in the portion of the country examined during this survey.

STREAM MEASUREMENTS.

The following table gives the monthly discharge in 1904 of streams in Strawberry Valley:

Monthly discharge, in acre-feet, of streams tributary to Strawberry Valley project, 1904.

Month.	Strawberry River.	Currant Creek.	West Fork Duchesne.	North Fork Duchesne.	Rock Creek.	Lake Fork.	Total.
January	1,670	1,420	1,360	2,970	3,560	7,160	18,140
February	1,570	1,400	1,370	2,960	3,000	5,720	16,020
March	1,670	1,750	1,380	2,970	3,060	5,360	16,190
April	5,810	4,220	2,880	6,080	9,060	9,040	37,090
May	23,050	10,260	14,680	33,560	31,320	25,600	138,470
June	8,700	6,040	10,100	43,960	46,640	40,360	155,800
July	3,620	2,900	3,440	15,360	20,720	28,840	74,880
August	2,490	1,330	1,980	7,200	10,400	20,760	44,160
September	1,760	1,010	2,800	4,680	6,360	13,300	29,910
October	1,670	1,050	1,640	3,260	4,420	9,840	21,880
November [a]	1,620	1,150	1,340	3,000	4,000	8,700	19,810
December [a]	1,670	1,300	1,350	2,990	3,840	8,040	19,190
Total	55,300	33,830	44,320	128,990	146,380	182,720	591,540

[a] Estimated.

CONCLUSION.

Beyond a doubt the reenforcement of the Strawberry from the streams farther east is not practicable. Were the canal constructed, its operation in the spring, when the flood should be delivered into the reservoir, would be extremely difficult where 150 miles of mountain channel was concerned. Furthermore, the construction of an aqueduct involving 7,000,000 yards of mountain material in open cut and 2,000,000 yards in tunnel as a minimum possibility is beyond consideration when compared with the benefits to be derived. Added to this estimate must be the 20,000 feet of tunnel out of the Strawberry Valley and two dams for the storage, besides the distribution system.

In view of this, the only possibility within the entire project is the utilization of the supply from the Strawberry alone. As indicated, this storage can be effected by a comparatively inexpensive dam not more than 32 feet in height and 280 feet long.

The discharge of the Strawberry, including Indian Creek, which could be readily diverted into the Strawberry Valley by a very simple channel, was 55,300 acre-feet during the past year.

The construction of an outlet tunnel 20,000 feet long to the lands in question, with a minimum section to carry the entire supply in July, August, and September, would be the large element of cost, the existing canal systems of Spanish Fork affording a basis for the distribution of the water. Under existing conditions a large acreage receives a May and June supply from Spanish Fork, and the supply for July, August, and September would be very valuable. It is thought that by this arrangement the storage of the Strawberry would finish out the supply for 25,000 to 30,000 acres, and that the landowners would willingly, and could afford to, pay a very considerable price for the improvement, which would probably amount to about $1,000,000 or thereabouts.

The Strawberry Valley will probably be reserved from entry until this suggestion is thoroughly analyzed and the people interested are given a chance to express their wishes relative thereto. Beyond this, further consideration will hardly be given to the diversion of the Duchesne into the Great Basin.

BEAR LAKE PROJECT.[a]

GENERAL STATEMENT.

The Bear Lake project is one of vast extent. Near Bear Lake Bear River makes a long detour to the north before passing from Idaho into Utah, where it discharges into Great Salt Lake. The lands that may be irrigated by its waters, under the contemplated plans, reach from Chesterfield, Idaho, on the north, to as far as Ogden, Utah, on the south. (See Second Annual Report Reclamation Service, page 476, for general map of Bear Lake basin.)

The first considerable body of land needing water is in Idaho, on both sides of the Oregon Short Line Railroad, from Soda Point to Portneuf River. It is included in Bancroft Valley, and is known as the Bancroft area. Most of this land lies beyond the rim of the Great Basin, in the drainage of Snake River. The portion draining into Bear River is comparatively small. There is no serious obstacle to the diversion of Bear River water over the divide.

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[a] From report by W. P. Hardesty.

The next body is the Marsh Valley area, reaching from McCammon to Red Rock Pass and lying in Idaho on both sides of the Oregon Short Line Railroad. This is all within the Snake River drainage basin.

The third area is Cache Valley, which is partly in Idaho and partly in Utah. Though already partly supplied with water, it contains much the largest and most valuable bodies of land needing water. There are three distinct parts to this area.

The fourth area is in Bear River Valley, in Utah, including the lower end of Malad Valley. It reaches south to Brigham City.

The fifth area, which would not be reached except by the development of the project to its utmost limit, includes the territory reaching on to Ogden.

Near Bear River the topography is peculiar, particularly below the lake. For long stretches the river has but little fall, but there are three long canyons in its course where the descent is very rapid. There are three localities where it runs for many miles through a wide flat valley with a sluggish current. Direct diversion in such sections would be easy, but unfortunately it would be necessary to construct a canal through very difficult country in order to reach the proper lands. In each valley the fall along the river is so light that no considerable body of land (unless marshy or wet enough already) can be covered in the valley itself. In two of such cases, those of the Gentile Valley, in Idaho, and of the Cache Valley, in Utah, the canyons below are so extremely rugged that construction through them would be exceedingly expensive. To maintain sufficient elevation to cover any but the lower lands it is desirable to divert at the upper end of a canyon in order to water the lands in the valley or valleys below.

For long sections in other places the river, while not in a true canyon, lies so far below the surrounding country that the bench lands adjoining can not be reached. These conditions make the problem of diverting the water and reaching the proper lands with it as formidable as that of the storage in the lake, and one requiring much investigation and extensive surveys.

A somewhat comprehensive idea of the project is given in the Second Annual Report of the Reclamation Service, pages 475-486; in a general way the operations of the past season have continued on the lines there outlined, but it has been found necessary to look into details more than is customary in an ordinary reconnaissance, on account of the scattered condition of the lands concerned and the topographic features of the country traversed by Bear River.

Only a small party has been engaged on the work during the season, but it was possible to obtain a thorough knowledge of all conditions and possibilities of the entire project except the portion relating to the diversion and storage in Bear Lake, a section thoroughly outlined in the Second Annual Report, pages 477–481. Much study will be necessary, however, before conclusions can be reached and the extent of the project defined.

Field work during the season was confined almost entirely to investigations and surveys relating to the diversion of Bear River onto the lands to be irrigated.

Measurements of the supply of water available for diversion to, and storage in the lake, have received much attention.

Detailed surveys made during the season of 1903 for the supply canals and outlet canal, and other works relating to the storage and control of water at the lake, were considered sufficient for all preliminary purposes. Detailed surveys for the diversion of the stored water after its return to Bear River were made in but one section, the Bancroft area, during that year.

Surveys to determine all the possibilities in diversion at different points, and to determine the upper limit of the land susceptible of irrigation, were carried forward on a comprehensive plan during the field season of 1904.

The following general plans or routes for diversion were thoroughly investigated and surveyed during the field season:

1. The Portneuf diversion. The diversion from Bear River would be at some point between Soda Springs and Grace, Bannock County, Idaho. The main canal would cross the divide between the Bear River and Snake River drainage basins, and, after traversing the Bancroft area, would discharge into Portneuf River. The water would pass down this natural channel for a number of miles, when it would again be diverted at a point in Portneuf Canyon. This lower diversion would first cover the Marsh Valley Lands, and then be extended through Red Rock Pass, where the main canal and its branches would reach the several sections in Cache Valley, both in Idaho and Utah, and finally, after passing through Bear River Canyon, would supply the lands of Bear River and lower Malad valleys.

This diversion is the highest one to be considered, and all the lands would be covered by it alone.

2. The Gentile Valley diversion. For this, the river would be tapped at or near Grace, Idaho. The canal would keep within the Bear River drainage, passing along the westerly side of Gentile Valley and over what is known as the Treasureton divide into Cache Valley. By this plan the Marsh Valley lands would not be reached, and Bancroft Valley (in part only) would have to be reached by a branch.

3. The Cache Valley diversion. By this diversion the river would

be tapped within or just above upper Bear River Canyon (included between Gentile and Cache valleys), and the canal system would cover the different divisions in Cache, Bear, and Malad valleys. The Bancroft and Marsh Valley areas would not be reached.

The foregoing diversions—three in number—are virtually alternate plans for reaching the lands desired to be irrigated, though they are different in scope. The first one is the most comprehensive.

Besides the main diversions, a survey for a special diversion was made. This would tap the river where it enters Cache Valley, and would cover the lands on the east side of the valley in the extreme south of Idaho and north of Utah.

It was intended to make only a close instrumental reconnaissance of all the different routes, but the actual work on most of the lines has approached a preliminary survey in its details. The transit and stadia method, with magnetic bearings (corrected for local variation), was used for the transit line. On all but a few unimportant lines elevations were carried forward by direct leveling. Nearly all the lines run were primarily for canals, with the secondary object of showing the upper limit of the lands that might be irrigated. Most of the lines run were virtually locations of a grade contour, the required fall for the canal being given.

Following are descriptions of the different diversion lines, with statement of results obtained by the surveys:

PORTNEUF DIVERSION.

DIVERSION FROM BEAR RIVER TO PORTNEUF RIVER.

DIVERSION AT SODA POINT.

This is the first of two surveys for diverting Bear River through the Bancroft country to the natural channel afforded by the Portneuf.

On page 481 of the Second Annual Report is a map of Bancroft Valley showing the line of the 1903 survey for a canal. This line will not be followed. The south part of the valley, including Tenmile bridge, is not shown.

The river, after passing through a comparatively narrow valley some miles in length, reaches at Soda Point the head of Bancroft Valley. This point is the northmost projection of the Bear River Range, which breaks off by precipitous cliffs to the river, which here turns southward.

The bed of the valley is of lava. The river runs in a deep gorge at the south side; the north wall is lava and the south one limestone.

About a mile west of Soda Point is the Portneuf divide, separating the drainage areas of the two rivers. This divide runs southerly from the north foothills, but soon swings to a southwesterly course, leaving a widening space between it and Bear River. The steepest fall on the south of the divide is southerly, while that on the north is northwesterly. The divide itself has a considerable fall to the southwest after a distance of 2 or 3 miles. The lowest point is near the southwest end, where it joins the foot of the mountain range that bounds Bancroft Valley on the west.

The river runs in a narrow rocky gorge from about 1½ miles above Soda Point to the Tenmile Bridge at Grace, Idaho, a distance of 6 or 7 miles.

Any diversion of Bear River into the Portneuf must, of course, be high enough to pass over the divide, and, if made in the gorge or canyon, the water must be raised to the general level of the country by means of a dam; otherwise the canal would have to run along the rocky side of the gorge till the grade line reached the top.

A line from Soda Point direct to the Portneuf affords the shortest possible route. The gorge has steeper sides and is better defined at Soda Point than at most places.

DAM AT SODA POINT DIVERSION.

At about the east end of Soda Point and about 2,000 feet southeast of Crater station (Alexander post-office) of the Oregon Short Line Railroad is an ideal dam site.

At the north side are lava cliffs breaking off perpendicularly from the sagebrush bench, and at the south side limestone cliffs standing at an angle of 60° to 75°. At the foot of the cliffs are lighter slopes, composed of débris from the cliffs.

The north cliff is 70 feet high, and its foot is about 12 feet above ordinary high water in the river. The south one is approximately 80 feet higher than the north one, but it does not stand perpendicular. The width of the gorge is about 225 feet at the top of the cliff on the north side. Between the foot of the cliffs it is only 15 or 20 feet less. The width of the river at high water is about 130 feet.

On making surveys to show the extent of the backwater basin that would be created by a dam it was assumed that the water level would be about 5 feet below the top of the north cliff, with the possibility of it being as much as 5 feet above it. By raising the water to the lower level the backwater would extend up the river for 5 or 6 miles to just above the highway bridge immediately southwest of the town of Soda Springs. For this distance a strip of varying width, on which there are several farms and a considerable area of cultivated land, would be flooded. For about 1¼ miles above the dam only the sides of the canyon would be covered, but above there the country opens out.

If the level be fixed 10 feet higher, much more land would be submerged. A short portion of the railroad would also be covered. The roadbed would have to be raised and made very substantial, as it is not practicable to change its location.

The fixing of the proper level will have to be considered in connection with the divide cut of the diversion canal.

CANAL FOR SODA POINT DIVERSION.

The first part of the canal will be the cut through the Portneuf divide. This broad divide, almost imperceptible except to close observation, has been already described. The depth of cut through it will depend on the height to which the water is raised by the dam. At the height assumed the maximum cut will be about 30 feet.

The canal survey runs westerly from the north end of the dam site, and the distance to a normal cutting, at the west slope of the divide, is over 1 mile. The material in the cut would be nearly all solid rock.

After passing the divide the survey crosses to the north side of the railroad, following its general course almost to the Portneuf. Nowhere along here is it over one-half mile from the track, and for much of the way it parallels the right of way on the north, the general course being northwest. At a point 16.3 miles from the head the line leaves the railroad (which here turns southerly down Portneuf Valley) and keeps on northwesterly, ending at Portneuf River, 17.5 miles from the dam.

The country for the entire distance has the peculiar topography common to lava regions, the formation being entirely lava. Over much of this region the lava is found at the surface; over nearly all the rest it is found 2 to 10 feet below.

The country is more or less broken and rolling, and there are many depressions that are not drainage channels and have no outlet. Thus it happens that a profile shows some long undulations notwithstanding the fact that the descent along the line (beyond the divide) is quite rapid, being about in the direction of greatest slope.

By deviating to some extent from the straight course of the railroad a much more uniform profile is afforded, but there would still be a number of cuts and fills.

The worst feature about this route is the great amount of surplus fall that has to be disposed of by drops in the canal. The total fall from the Bear to the Portneuf is 350 feet, to which would be added about 75 feet by the raising of the water at the dam. Allowing the ordinary gradient of 1.58 feet per mile for the portions between drops, there remains about 395 feet that has to be put in drops. While a solid rock formation is ordinarily the best material in which to dispose of surplus grade-fall, the lava formation is decidedly objectionable. The lava is much broken up with many deep fissures, and is usually a very unfavorable material in which to excavate a water-tight channel. It also lacks continuity at shallow depths, masses of it being interposed with earth deposits, and often thin layers of it are underlain with a clay formation. Experience with existing canals in the lava in this region has shown that it is best to excavate in the lava as little as possible, making a channel for the canal by use of embankments where earth is at hand. Over much of the region the molten lava in cooling has apparently been so badly shattered that water may escape through it to considerable depths. The drops will be very expensive. There are no natural sites for them, and to reduce their number a section of canal in light fill will be required above each and a section in heavy cut below.

DIVERSION NEAR GRACE, IDAHO.

This is the second of the two routes for diversion through the Bancroft country to the Portneuf. The head would be 5 or 6 miles below that of the upper route, near the highway bridge at Grace.

As before stated, the Portneuf divide is lowest near its junction with the foot of the mountains at its southwest end. The saddle here fixes the minimum altitude of the diversion point.

Over the northern and western part of this region, known as the Bancroft country, and the eastern and southern part, known as the Soda, or Tenmile, bench, the formation is lava. This extends over all the plains portion of the region. The formation in the surrounding mountains is either limestone or quartzite.

West and northwest of Grace a slope leads out from the mountains and gradually tapers out into a plain or bench. This slope in most places has a deep soil.

CANAL LINE FOR GRACE DIVERSION.

The lower part of the slopes where there is no rock and where the material is at the same time well adapted to resist erosion furnishes an almost ideal location for a canal. A line here is preferable to a line confined to the bench, as it allows comparatively short and inexpensive drops to be made, thus disposing of the great amount of excess fall in the country. The canal can be run on a supported grade along the slope, and when it begins to run into objectionable ground, with steeper side slopes, it can be dropped down to a lower level.

The vast superiority of a line along the foot of the mountains to one upon the bench makes it desirable to traverse the lava and reach the west side of the valley as quickly as possible. A canal heading as far down the river to the southwest as practicable meets these conditions.

The surveyed line starts from the river just below the Tenmile bridge. It runs westerly for 6 miles, to near the foot of the mountain, then turns northerly and passes through the saddle before mentioned with a light cut at 7¼ miles from the head. In less than a mile more the line reaches the foot of the hills, and for 12 miles beyond runs through an excellent material for economical construction and safe maintenance. In this distance there are seven drops, aggregating 92 feet.

These drops serve to keep the line on the tapering slope leading out from the hills, but yet above the main flat or bench, which is of lava. On the slope the earth extends to a depth quite sufficient for a large canal excavation, the underlying formation being either limestone or quartzite. The line runs just easterly of the foothills to a point about 20 miles from the head, where it approaches the Oregon Short Line Railroad. It then turns northwesterly, keeping away from the foothills, as does the railroad, and crosses to the north side of the railroad at 23.5 miles, continuing on the same course to the Portneuf. Its total length is 24.4 miles.

The lower section of 4.4 miles is over a lava formation, and, as it is not on a hillside, the item of drops is of more importance than farther back. The first section of canal, about 8 miles, and the lower one of 4.4 miles would be over a country with lava formation. For much of the distance the lava rock is far enough below the surface to be clear of any ordinary excavation, but in other places it is at the surface. For the middle section of 12 miles no lava and very little other rock would be encountered.

For a stretch of more than 1 mile, extending from shortly above the Tenmile bridge downstream, Bear River is not nearly so far below the adjoining country as it is in the gorge. Below this stretch the river has again cut down through the lava until a maximum depth of about 300 feet is reached.

DAM AT GRACE DIVERSION.

To divert a canal in either of these canyons would require a dam to raise the water to the surface of the bench, or else a section of conduit of some variety to convey the water along the rocky sides (often perpendicular) to a point where the grade line would reach the surface.

Several sites for low diversion dams were surveyed, and it is probable that the choice will be of one at the upper end of the lower canyon. This would shorten the canal by about 0.9 mile.

A dam 24 feet high, 450 feet long on top, and 100 feet near the bottom, would be needed. It would have to extend some distance on each side of the bank to reach natural ground of sufficient height. The structure could be of masonry, the rock for which is at the site, though the sand would have to be hauled several miles. The haul of cement from the railroad would be about 6 miles. The bottom and sides of the channel are of solid rock. A lower diversion dam, though the river is wider, can be built farther up, about the only disadvantage being in the extra length of the canal needed. It would not be above the lower end of the upper canyon, which is about one-fourth mile above the head of the survey. The canal would be on the bench from the start.

ALTERNATE LOCATION FOR GRACE DIVERSION CANAL.

Some distance can be cut off of the line before described by diverting higher up. A line about 20 feet higher in elevation was run. This starts from the lower end of the upper canyon, and, on account of bearing farther away from the river to the north, gives a shorter route to the western foothills. The survey rejoins the main (low-level) canal line nearly a mile north of the saddle in the divide.

As compared with the main line its advantages are (1) that it will save 0.6 mile in length; (2) that it will avoid two long fills and one cut; (3) that the control of the additional land secured by the branch line will be 20 feet higher, forming a strip encircling the valley to beyond Chesterfield. Its disadvantages are (1) that it will require a much higher diversion dam than the lower line, if the latter be diverted near the bridge; (2) that considerably more of it lies in rough and broken lava formation and that lava closely underlies it all; (3) and that 0.6 mile of it is on an unsupported grade, requiring more expensive drops, exceeding those of the other line by at least 3, and, in total fall, by 20 feet. The advantages gained are entirely outweighed by the disadvantages.

SURVEY FOR SHORTENING CANAL.

Detailed surveys were made to ascertain the practicability of using as part of the canal a natural channel leading from a point about 1¼ miles northwest of Bancroft, at the railroad, to its discharge into the Portneuf, which is at the same point as the canal survey. Its use would obviate the construction of between 5 and 6 miles of canal. The conclusion from the surveys and examination was that the scheme is hardly practicable.

Southwest of Lund, Idaho, there is a divide in the range of mountains, which is lower than adjoining portions. On the west of this is the valley of Fish Creek, which drains into Portneuf Canyon at a point far below the proposed discharge of the diversion canal. If it were feasible to tunnel through this divide from some point on the diversion line that heads near Grace, over 10 miles of canal could be cut out. A survey made for this tunnel, however, showed it to be wholly impracticable.

COMPARISON OF GRACE AND SODA POINT DIVERSIONS.

Comparing the Grace and Soda Point routes, the advantages of the lower diversion, near Grace, over the upper one, at Soda Point, may be summarized as follows:

(1) Two hundred feet less surplus fall to be disposed of by drops.

(2) Excellent material in which to construct and maintain a channel for about 12 miles of its length.

(3) No high dam and no expensive divide cut required, and no flooding of land by backwater.

(4) A location, for all but the lower 4.4 miles, that affords a uniform supported grade between drops and that reduces the number of the drops to a minimum, separated by long intervals.

The advantages of the Portneuf diversion are—

(1) It is by the most direct line possible. The distance to the Portneuf in an air line is less than from points lower down the river, and the very direct alignment of the survey combined with it makes the length nearly 7 miles shorter than the lower diversion line.

(2) It completely controls practically all the land in the Bancroft area. Its position at the head of the main valley allows a branch to be located out to the north side and also one to the south, thus covering the valley, while a branch from the lower diversion would have to encircle the valley, and would probably not reach much more than one-half of it.

IRRIGABLE LANDS IN BANCROFT VALLEY.

The altitude of Bancroft Valley ranges from about 5,300 to 5,750 feet above sea level.

There is much hard wind, which has a free sweep, unbroken by mountains or timber for most of it. The location is well northward, the latitude being about 42° 40′. All this causes a distinctly cold climate, subject to frosts during all but about two months of the summer. Only certain plants can be successfully grown.

The soil is usually shallow, the lava rock lying at an average depth of 1 to 6 feet. The occurrence of lava outcrops causes some loss of land in most large fields, and also renders cultivation difficult. The land is usually rolling or broken, so that a greater number of laterals is required to cover it all. There are many slightly raised portions, to reach any one of which requires a fill for the lateral.

The valley is already supplied with two canal systems—that of the Consolidated Canal Company, which owns the Soda canal and its main north and south branches, and that of the Last Chance Canal Company. The former system has depended on Soda Creek for its supply, but its canal is being extended up to another smaller creek, called Spring Creek, which runs on the east side of Soda Springs.

Though designed to water most of Bancroft Valley, the service from this system has been so extremely poor for nearly all the land under it that unless it is radically improved the canal will not be an important factor in the reclamation of the valley. An insufficient water supply and the loss of much of this along a section of canal built through a porous formation appear to be the main causes of the inadequate service.

The Last Chance canal system, taking water from Bear River, was designed to cover only the portion of the region known as Tenmile bench, which lies south of the main part of the Bancroft area. Extensions of its branches and the partial use of a large lateral of the Soda canal for conveying the water has made it possible to run Bear River water to points several miles northwest of Bancroft.

The elevation at which the water is diverted from the river makes it possible, if no grade is thrown away in the canals, to cover much the greater part of the entire Bancroft country by the Last Chance canal system.

For the reasons given, Bancroft Valley lands are decidedly inferior to those lower down under the Bear Lake project. The feature that causes them to be considered at all is their location. They are nearest to the storage supply, and diversion to them would be much shorter and more direct than to any other of the main areas, whether the main diversion of the river be here or farther down.

The estimate given in the Second Annual Report of the Reclamation Service, pages 480–481, is considered to be quite conservative for the storage and control portion of the project. The pro rata cost of this, added to that for the diversion system traversing the valley, should not make the total cost per acre more than $15. The net area of the land worth reclaiming is put at 35,000 acres. There are large tracts that are practically valueless, and much of the rest has considerable waste land—too broken or having too much lava at the surface to be anything but third choice. Taking the Portneuf diversion as a whole ,the existence of the Bancroft Valley lands is a strong factor that may influence the choice of this diversion in preference to any lower down, but it is by no means the only factor.

DIVERSION FROM PORTNEUF RIVER.

This would be the second or lower division of the Portneuf diversion. Under it would lie all the main bodies of land except those in Bancroft Valley. The elevation of the Portneuf where water is received from the upper division is such that very much fall has to be thrown away before the water is again diverted. The river here enters Portneuf Canyon, down which the water would flow for a number of miles before being diverted.

The features that determine the point of diversion from the Portneuf are (1) an elevation at least high enough to get through Red Rock Pass; (2) an elevation as much higher than the last as would be practicable, to allow of covering the high-lying lands in Marsh Valley without too great expense; (3) an elevation that would avoid as much steep side-hill work and broken country as possible. The latter (especially for work in the canyon) would be the main feature that would fix the upper limit for the diversion point.

The point selected for the diversion survey is at the head of the canal of the Portneuf Irrigation Company. This is just above a series of falls in the river, including the most important falls, at which there is a drop of about 27 feet. There is very little fall for 2 or 3 miles farther up, and no very rapid fall is found until the Hot Spring is approached, about 6 miles above the proposed diversion. The head of the survey is at the head of the Portneuf canal, in the canyon, about 6 miles above McCammon and 1 mile below Topaz siding of the Oregon Short Line Railroad. The grade used is 1.58 feet per mile.

CANAL LINE.

The line for 1¼ miles follows the upper side of the Portneuf canal, the transverse slopes being unusually steep. As the old construction would interfere with the new, the most practicable method for this section would be to enlarge the Portneuf canal so as to carry the water for both canals. Below this section the country opens out, and the line gradually departs from the existing canal, the grade of which is between 4 and 4½ feet per mile. It soon reaches the bench, outside of the canyon proper, and turns rapidly away from the Portneuf, passing about 3 miles southeast of McCammon.

Up to the 5-mile point the surface is fairly uniform, allowing of good alignment. From there to about the 20-mile point most of the ground is more or less broken. It is not at all bad to build in; the transverse slopes do not exceed 15°, and usually are not over 8°. The material is nearly all earth and should not erode nor slide easily. The main objections are the excessive curvature and length, caused by the long succession of broad ridges and gulches to be crossed. These are not serious obstacles to good construction, but cause much sinuosity in the line. About 15 miles from the head Arkansas Creek is crossed. The survey calls for an inverted siphon 375 feet long, with a maximum head of 75 feet. Through most of this broken country the line would be bettered considerably if made 50 to 150 feet higher, as the ground above is not so badly cut up by alternate ridges and hollows.

From the 20-mile to the 28-mile point the land is better suited for farming, and the ground is much more uniform and favorable for a canal. Then, as the line approaches Red Rock Pass, the country rapidly becomes more broken and construction will be more expensive. The Marsh Valley body of land contracts to a narrow strip, so that the Marsh Valley section may be considered as ending here, only a mile south of Downey.

MARSH VALLEY LANDS.

All the lands between the Oregon Short Line Railroad and Marsh Creek would be covered, besides a large tract east of the railroad. The area covered reaches from McCammon south beyond Downey, or to the north end of the narrow valley that includes Red Rock Pass. At the north end a large part of the land from McCammon to Oneida is already irrigated from the Portneuf. The tract covered east of the railroad averages from one-half to 1 mile in width. Most of the best land between the railroad and the mountains, reaching for 7 or 8 miles north and south, with its center in the Ninemile settlement northeast of Downey, is not covered by the line. Much of it is now dry farmed. The soil is mostly clay, and near the railway the first 3 or 4 feet is mixed with gravel. The clay extends to a great depth, as determined by driving wells. West of the railroad the formation is mostly gravel, often of much depth, and it takes more water, and is otherwise less desirable than the clay lands. It is also more broken than the land east of the railroad. Very little of it has been cultivated.

The extent of reclaimable land under the survey in Marsh Valley is limited, and probably 10,000 acres will cover the amount of really good land—that not broken nor of gravelly formation.

The climate is much superior to that of Bancroft Valley, and the lands will stand a higher cost of reclamation.

The clay lands east of the railroad are worth reclamation at a cost of $25 to $30 per acre, and the cost chargeable against them would not exceed these figures.

A canal 100 to 200 feet higher would cover a much larger body of choice land east of the railroad. It is doubtful, however, if this would warrant the placing of the point of diversion that much higher up Portneuf Canyon.

The lands covered by the survey form an important factor in influencing the diversion from Bear River by the Portneuf route.

RED ROCK PASS.

The line passes over the edge of the bench lands about one-half mile south of Downey, and from there extends to the south end of the narrow valley, including the pass, a distance of about 11 miles. Most of the country traversed is broken. It is necessary to go through the pass to reach Cache Valley, to the south.

Red Rock Pass is a noteworthy topographic feature of much geologic interest. It is the outlet for the ancient basin called Lake Bonneville. The bottom of the pass is from 360 to 375 feet below the high-water mark of the prehistoric lake, and is at the well-defined watermark or bench level called the Provo shore line. This mark is well defined farther south, and is a controlling feature in the location of the proposed canals in northern Utah. The water surface of Lake Bonneville remained at the level of the bottom of the pass for long ages. From the low summit of the pass, at Red Rock, the drainage is to the north and to the south.

The valley each way from the summit is flat and marshy, averaging from one-fourth to one-half mile in bottom width. The mountains or their projecting mesas (benches) and foothills are close on either side. To maintain the desired elevation the canal must be built along the slope at one side of the pass, averaging 100 to 125 feet above the bottom. This throws the construction into broken and sidehill country for most of the way, much of which would be avoided if the line could be kept near the bottom of the pass.

From the 28¼-mile point (1 mile south of Downey) to the 32-mile point construction will be expensive. The ground is much broken, there being an almost continual succession of small ridges and hollows. The material is mostly gravel, much of it cemented, and for a mile or more there would be a great deal of conglomerate rock excavation.

The canal from the Portneuf is on the east side of the valley, and as the main bodies of land south of the pass can only be reached by a canal built along the west side of Cache Valley it is necessary to cross over. An inverted siphon is required for this. The narrowest place in the valley is at the pass itself.

The choice of the location for it is complicated by the necessity of having a canal on the east side as well as the west side south of the pass in order to cover the east side of Cache Valley.

Other things being equal, it is desirable not to split the main canal (to form the east-side and west-side branches) until near the south end of this difficult section. To cover all possible routes the surveys for both sides were begun north of the pass. Four lines for possible siphon crossings were run across the valley at and near the pass.

The country on the west side is much less difficult than that on the east, so that it may be best to cross to the west side at the northernmost line with the main canal. This would require another siphon crossing to return water to the east side for the east branch. The location of such would be near the southernmost of the siphon surveys.

The line started from the Portneuf was continued through on the east side, though south of the pass it serves as a survey for only the east-side branch. The survey for the west-side branch (really the main canal) starts from this line near the pass.

On the line from the Portneuf the country is more favorable from the 32- to the 33.2-mile point, lying below the steeper slope from the high bench. Beyond, to the 34-mile point, it allows ecomonical construction. Here is reached Marsh Creek, which comes out of the mountains to the northeast. A siphon line 535 feet long, with a maximum head of 35 to 40 feet, is required to cross the narrow valley in which it runs. South of here the country is much more broken and rocky. Another short siphon and some expensive canal work will be necessary. The line passes back of the high rock knoll that forms the east side of the Red Rock Pass proper. There would be much rock work up to the 36-mile point, with some points where only a flume or pipe would do. Beyond there it would be nearly all earthwork up to 41.3 miles, though the country is much broken by a succession of ridges and hollows. The valley of Swan Lake Creek causes a long detour.

At the 41.3-mile point the character of the country again changes. The hills on the east side of the valley draw in and the bench land about disappears. This contraction of the valley becomes greatest at about the north end of Swan Lake, about 1 mile farther. This, though a lake of some size, is simply a depression in the marsh that covers the bottom of the valley. Much broken side-hill country, with a considerable section in both loose and solid rock, is encountered to the 42.7-mile point opposite the south end of Swan Lake. Beyond here the country is much better, and the narrow valley rapidly opens out into the north end of Cache Valley. This point is the end of the section that includes Red Rock Pass and its approaches, which begins only about a mile south of Downey. It may be called the Red Rock Valley.

Of the siphon lines for crossing Red Rock Valley the first is included in a survey made for an alternate location for part of the main canal. It leaves the line coming from the Portneuf at the 33.2-mile point.

There would be 0.7 miles of canal before reaching the point for the siphon. The latter would be 1,700 feet long. The maximum head from the east end would be 103 feet, and 1,160 feet would have a head of not less than 100 feet. A hydraulic grade fall of 11 feet was allowed. The line is north of the pass. This is probably the best siphon location that can be secured.

The line continues on down the west side of the valley to a junction with the west end of the second siphon location. It passes directly through the prominent landmark, Red Rock.

The second siphon survey leaves the Portneuf line at the 35.2-mile point, just south of the pass. The line has a total length of 2,750 feet, of which about 2,400 feet would be in pipe and the balance canal, the latter being possible by reason of a high ridge or island near the west side, over which the line runs. The maximum head under the east end is 98 feet. One thousand feet of the line is on marshy ground. Eleven feet in grade fall was allowed. This location for a siphon, including the sections of canal adjoining, is an alternate route for the first one, but is distinctly inferior to it.

The third location for a siphon is one that crosses the middle of Swan Lake. It leaves the east side canal at the 42.3-mile point. The length is 2,080 feet, of which about 1,400 feet are in the lake. The maximum head from the east end to the lake level is 94 feet.

The fourth or lowest location is the one crossing the south end of Swan Lake. It runs from the 42.7-mile point of the east side line. The length is 2,940 feet and the maximum head 94 feet.

The third and fourth locations are alternate routes for the one plan of having the crossing as near to the south end of Red Rock Valley as possible. This plan has two variations, however—one to keep the main canal on the east side up to this locality and then to cross over, and the other one to let the main canal cross north of the pass to the west side and return a branch for the east side at Swan Lake.

The location of the canal system through Red Rock Valley, with the choice of several different plans, extending, as it does, for a distance of about 15 miles by the canal survey, is one giving room for much study.

BRANCH FOR CUB RIVER LANDS.

This survey is a continuation of the line started from the Portneuf. The country rapidly opens out south of Swan Lake. The line turns off to the southeast, leaving a rapidly widening strip of arable land below it.

The country is rolling, with drainage to the west. A large area below the line, especially at the levels next above the flat marsh ground, is already under cultivation, though mostly dry farmed.

The ground traversed is in the main suited for economical construction. The line is somewhat devious, the detour around the valley of Stockton Creek causing the greatest lengthening. From the south side of this creek (44-mile point) the area of virgin land rapidly increases in width.

The soil all along is mostly clay and of good quality, as indicated by the luxuriant growth of sagebrush. The country is somewhat rolling near the line, and there are many elevated portions of ridges that would be difficult to irrigate.

Outside of some land along Battle Creek, nearly all the cultivated land under this section of canal is dry farmed. However, some water that is stored in small reservoirs is used during the flood season.

From the 47.2- to the 64.7-mile point the country along the line is more rolling than before, there being many ridges and wide flat gulches that require much winding in a canal line unless heavy cuts and fills be made. The material is all earth, and can be moved at a low cost.

At 64.7 miles the line reaches the edge of the bench facing Bear River. It is desired to reach the large body of land east of the river extending from Preston south into northern Utah. This requires a siphon crossing of the deep valley of the river, which lies between high benches on either side. To make a detour around the sides of the valley with a supported canal grade would be entirely impracticable. Even if the river could be crossed at grade a few miles up, the plan would be much inferior to a siphon crossing. The sides of the valley or gorge are steep and the material is mostly clay that slides easily when saturated with water. The siphon will be located near the line that was run.

The problem is to have as short a siphon as possible and at the same time to have the southeast end reach the top of the bench, thus avoiding the use of a canal along the steep clay banks. The benches on the two sides have about the same height, but the large fall in the hydraulic grade required for economical pipe construction makes necessary a landing place considerably lower than the head. The benches have a rapid fall to the southwest along the river, so that it is possible, by making the crossing somewhat askew, to reach the top of the east bench. The line as run has a horizontal length of 6,335 feet. The actual length of pipe would not be over 100 feet more. The maximum head, referred to the northwest end, is 325 feet, this being over the river bottom. For 3,380 feet the head is not less than 300 feet. Along the steep slope on the east side runs the small Preston canal, taking water from Mink Creek, a tributary of the Bear.

The Preston canal reaches the top of the bench about one-fourth mile southwest of the end of the siphon line. A grade fall of 35 feet was assumed for the pipe. From the east end some expensive canal construction would be necessary to cut through the edge of the bench and out to grade to the south. This section would be nearly one-half mile long.

The siphon crossing should be so located as to swing the southeast end about one-fourth mile to the southwest. The length of the pipe would be 100 to 150 feet more and the ground rather more unfavorable, but a short light cut would bring the canal out to grade on top of the bench.

On getting out into the clear on the bench the survey was ended, at a distance of 66.25 miles from the Portneuf. From this elevation can be covered all the country from Preston south into northern Utah. The point is between 60 and 70 feet higher than the Oregon Short Line Railroad station at Preston, 3 or 4 miles away to the south. The country is open, and canal construction would be comparatively simple.

The east-side canal system thus covers two distinct bodies of land on opposite sides of Bear River. The first body, which might be called the Battle Creek section, is less developed than the other. A large part of the land is still sagebrush, and of that cultivated the greater part is dry farmed.

The cultivated land in this locality is mostly below the survey, but for the lower 6 miles most of the land above as well as below the survey is under cultivation.

The irrigable area can only be approximated at present, but there is probably not less than 10,000 acres of good land that should stand a cost of $30 per acre for a permanent water right. The land east of the river is treated under the head of the Lewiston flat line.

WESTERN CACHE VALLEY SECTION.

The line that was run for western Cache Valley leaves the line from the Portneuf directly south of Red Rock Pass and crosses over to the west side of the valley by the second siphon location before described. The line was continued from Cache Valley on through the dividing range into Bear River and Malad valleys.

There is considerable broken country encountered before leaving Red Rock Valley. The ground is much more favorable for construction than on the east side of the valley. On the west side, south of Red Rock, there is a broad sloping bench between the mountains and the valley. The grade level of the surveyed line was found to be about 20 feet too low to take advantage of the best location over this bench.

The line is forced out onto the slope next to the valley for much of the way. If higher, use could be made of two natural depressions in the top of the bench for cutting through back of raised portions next the valley. A total saving of at least 1½ miles in length and the avoidance of much rock and steep side-hill work can be made by use of long divide cuts, if the grade be made 15 or 20 feet higher. This elevation can be obtained by using a lighter grade for the canal from the Portneuf and a less fall for the siphon. With this gain in grade elevation the west-side route for the main canal through Red Rock Pass will probably be superior to the one on the east side.

The surveyed canal line does not fairly leave the broken country contiguous to Red Rock Valley till it reaches a point about 8 miles from the siphon. Here it turns off to the southwest, toward the town of Oxford. The same grade rate, 1.58 feet per mile, is used as on the other lines.

The country traversed, till a point about 1½ miles south of Weston is reached, is, in the main, fairly favorable for canal construction.

There is a stretch of about 3 miles between Oxford and Clifton where many loose bowlders are encountered. Near Oxford, for a considerable distance, the line is along a bench slope covered with loose rock. There should, however, be little difficulty in constructing a good safe channel. In places the ground is broken by drainage channels. The area of land needing irrigation is comparatively small as far as the vicinity of Clifton, as the main flat between Oxford and Clifton is mostly a marsh. Part of this area is, moreover, already supplied from large springs in the mountains. The main body of land in West Cache Valley lies beyond Clifton. The only considerable stream at all issuing from the mountains to the west is Weston Creek. The most desirable area is on the west of the Oregon Short Line Railroad; it averages less than 1 mile in width to near Weston. The eastern limit is Deep Creek to its junction with Bear River, and then the latter. By the surveyed line, the towns of Oxford, Clifton, Dayton, and Weston are approximately at the 11-, 17-, 23-, and 29-mile points, respectively. A large detour to the west to head the valley of Weston Creek is required, and at 34 miles the line crosses from Idaho into Utah.

Here may be mentioned the project of the Oneida irrigation district. This district was organized under the irrigation-district laws of Idaho for the purpose of using the water of Mink Creek, a tributary of the Bear, for irrigating a large body of land in the north and northwest parts of Cache Valley. The canal would cover nearly all the land that is covered by the reclamation-canal survey for the section from Clifton to the State line. The located line runs alongside the latter survey, only it is 9 to 13 feet lower. Its construction would affect the design of the Bear Lake system.

Directly south of Weston, at the 32.6-mile point, the character of the country immediately along the line changes greatly. This point is at the north end of the easterly slope of a long isolated spur from the main range of mountains. On this slope the Provo shore-line stage of Lake Bonneville is well defined, though it is hardly apparent along the section from Red Rock Valley to this point. Southward for nearly 7½ miles the line runs along the east slope of the spur at a height above the bench ranging from about 25 or 30 feet at the north end to 10 feet at the south end.

This bench has considerable slope where narrow, but is almost level where it has considerable width. The slope above and below it is steep, and rock often appears at the surface. The bench offers a location for a canal vastly superior to one above or below, but the grade fall of a canal makes it impossible to take advantatge of it except for a limited distance. For the section in question the canal should be about 20 feet lower. If 20 feet higher it would be much worse. Farther south, however, the descending grade line strikes the top of the bench, securing its full benefit; for the canal below Bear River Canyon and the one south of Cache Junction the line is too low, being mostly on the slope below.

In the section reaching from the 32.6 to the 39.9 mile point the bench is usually narrow; it is often only 200 feet wide. Most of the line is low enough to avoid the steeper slope, being on the tapering slope connecting it with the bench. On the latter slope the surface is usually covered by broken rock and earth coming from the slopes above.

On this section construction will be expensive on account of both the steep slopes and rocks. The surface is broken by gulches large enough (at least three of them) to require siphon crossings. Two of the gulches, all of which are narrow and deep cut, are over 100 feet below grade.

At 39.9 miles the survey leaves the slope facing the main valley and turns westerly over the summit of a very broad saddle or divide separating the north and south parts of the long spur of the mountains before noted. The topography is peculiar. The saddle is a bench at the general level of the water mark the line has been following. If the grade were over 8 or 10 feet lower an excess cut would be required to get through. The country to the west of the saddle drains into the creek known as Clarkston or Newton Creek.

A supported grade line runs far up the broad basin of the creek east of Clarkston, but much distance is saved by the survey crossing a narrow place by a high trestle flume or a siphon. The crossing would be over or just below the Newton reservoir, which is formed by damming the creek. Three alternate crossings were surveyed.

With the exception of this creek crossing and one heavy cut beyond, there would be inexpensive canal construction from the 39.9- to the 47.1-mile point. In this section is covered some of the best land under the project. The area is mainly tributary to the town of Newton. A large area of fine land would be left above the canal. To find the area above the creek crossing that can be covered a branch line was run. This encircles the flat basin in which is contained the Newton reservoir. This branch covers land as near to Clarkston as can be reached. The town of Clarkston and most of its tributary country are above the survey. Though a very desirable locality, it is doubtful if this would warrant building a canal at a higher level all the way from the Portneuf. For the area covered in this, the Newton section, the land should stand a cost of $40 per acre for water, and the actual cost may approach this.

Beyond the 47.1-mile point the country continues, in the main, favorable for construction to the 48.7-mile point. At 48.5 miles is the head of the branch to the east side of Bear River for the country south of Cache Junction. At 48.7 miles the Provo bench (which the line has been following) practically disappears. This is at the approach to Bear River Canyon. This canyon is a deep rocky gorge cut through the range of mountains that bounds Cache Valley on the southwest.

The line continues along the fairly steep slope below the higher benches. The country is broken by ravines, with outcrop of rock in places, but there would be no specially expensive and difficult work until the 49.3-mile point is reached. Both on account of its location and of the ground becoming more rocky, this is the north end of a site for a tunnel that would be an alternate plan for reaching the lower end of the canyon.

On the west side of the most contracted portion of the canyon is a prominent rock peak, back of which is a saddle. This saddle is approximately 300 feet above grade, and is about 75 feet below the Lake Bonneville high-water mark, which is well-defined here and forms the west side of the saddle. The mountain range continues in its rise to the northwest. The existence of the saddle, with a large gulch near either side, makes the topography such that a natural route for a tunnel lying west of the canyon is afforded.

The line as surveyed follows the general grade contour on down the northwest side of the canyon. The ground is not nearly so difficult as that along the Bear River Canal Company's main west-side canal, which is diverted from the river at the head of the canyon. Its level is about 380 feet below that of the survey. It runs near the bottom of the canyon, where the slope is much steeper.

From the tunnel site the line reaches the face of the slope next to the river in about 700 feet. From there the line is fairly direct for about 3,000 feet, when it turns back from the river to head a large gulch, having traversed the main part of the canyon.

This stretch of 3,000 feet would probably have to be flumed. The material is nearly all loose rock. The slopes are not excessively steep, but the expense of the rock excavation, the lack of earth for the lower bank, and the liability of rock slides combine to make a canal inadvisable.

In the gulch the ground continues broken, though there is less rock. A flume would probably be necessary, as it is more reliable than a canal, though the necessity for its renewal would be decidedly objectionable. The gulch is so extremely deep that a siphon crossing near its mouth would be expensive. The line runs for 2,000 feet up this gulch before striking the bottom. At this point is the possible southwest end of the tunnel before noted.

The tunnel would be not over 3,000 feet long. The rock formation is apparently one that shatters easily and the tunnel might require lining with concrete. At any rate all seams and fissures would have to be well plastered.

A heavy gradient was given so as to permit a moderate section. The cost completed should not exceed $30 per lineal foot.

From the end of the tunnel site the country is extremely broken and rocky around to the crossing of the south fork of the same gulch. This calls for a siphon, the drop being 90 feet. The best plan would likely be to extend the tunnel southward to this gulch, locating the end farther up the gulch. The ground from here on to the summit of the ridge next south—a distance of 0.3 mile—is such that a safe channel would be very expensive. From here (at 50.9 miles) the country opens out into Bear River Valley. The line is now fairly out of the canyon. As the elevation is far above that of the main bodies of land, and as construction at this level would be very expensive, a drop is necessary. This is made after extending the line about 0.3 mile around to the west to secure an unbroken slope. The line is about 20 feet below the Provo watermark, and so can not take advantage of the nearly level bench at this height. The material is mostly rock. At 51.2 miles the main drop in the line is made. This amounts to 185 feet in a distance of 2,300 feet.

A wide limit is allowable in fixing the lower grade level, as there is no particular controlling feature. The idea is to cover the main body of desirable land in the valley and at the same time keep far enough away from the mountain range to avoid rock and all steep transverse slopes.

EXTENSION TO BEAR RIVER AND MALAD VALLEYS.

The southern part of the former valley is already covered by the Bear River Canal Company's system, which takes water from the river at the upper end of the canyon. Above the canal there is only a small supply of water used for orchards and gardens. The valley west of the river is occupied by a broad bench of excellent land. The results achieved under the existing canal indicate what can be done with irrigation in this valley. The survey leaves the foot of the 185-foot drop at 51.7 miles from Red Rock. The same grade of 1.58 feet per mile is used.

The country is but little broken and is favorable for construction. The general course of the survey is northwesterly, the line passing through the upper part of the town of Plymouth, near the 58-mile point. Less than 2 miles west from here is the junction of Bear Valley with Malade Valley, on the north. The latter is named from Malade River, which traverses its center.

This river also passes through Bear River Valley. The bench, including the main body of lands in this valley, narrows rapidly from the canyon up to the point described, north of which the surrounding country drains directly into the Malade. Malade Valley is narrower here than for many miles farther up. The descent of the river and valley to the south is extremely gradual, the former falling only 2 or 3 feet per mile for much of the way.

Hence if water is to be conveyed to the west side of the valley, to cover any considerable area, there is required either a siphon for a direct crossing or a canal line that must make a detour around the entire valley. In the latter case the canal will run far northward into Idaho to above Malade. Unless it be desired to cover the lands this far north, the plan of piping across the lower end of the valley seems best for reaching the west-side lands. The broadly defined line between the two valleys, before noted, is about the narrowest place, and this was chosen for the crossing. At 59 miles the drop is begun, it being merely an approach to the siphon. Grade at the west end is so much lower than at the east one that the fall is far in excess of that needed for the hydraulic head.

The distance across is 9,700 feet and the west end is 103 feet lower than the east one. It is 80 feet higher than the edge of the bench next to the river and is 120 feet above the river. The distance across between banks (benches) is over 900 feet. The approximate length of the siphon, allowing ample head, is about 7,800 feet, and the maximum head to which the pipe would be subjected is about 140 feet. Carrying the water up the west side to as high as the east side elevation will allow is not considered as fully warranted, the expense and the land being compared. From the west end of the siphon the plan is to run branches both north and south. The main survey line was continued for the branch to the south, covering the land of the west side of Bear River Valley. This area is much less than on the east side, it being a strip nowhere over three-fourths of a mile wide. Southward the width gradually decreases. The survey was ended at the 70-mile point, which is about one-half mile south and 1 mile west of the center of the town of Riverside. The line is here 2,100 feet west of and 77 feet higher than the Bear River canal. There is considerable land reaching farther south that would lie between the two canals, but the country becomes so rough that a drop should be made to avoid expensive construction. Only a small lateral would ever be extended over it.

The total area in Bear River Valley included between the survey and the existing canal is about 11,000 acres, practically all good land.

It is claimed by residents that the value (now $10 to $20) would become $100 per acre if watered. Probably $50 for water would be warranted. The distance to the lower end of the survey from the Portneuf is 105 miles. Adding to this the diversion across the Bancroft Valley would make the total length of artificial channel about 130 miles. With the pro rata cost of this and the storage works the expense of supplying water to Bear River Valley may run from $40 to $50 per acre.

From the siphon crossing a line was run up each side of the valley designed to cover all but the higher slopes on each side. This was done near the end of the field season, so that the results are not available at present.

EXTENSION TO EASTERN BOXELDER COUNTY.

The survey to cover this body was made at the end of the field season, too late for the results to be available for this report.

The plan is to branch off from the west-side canal at the summit of the high ridge at the mouth of Bear River Canyon, at the 50.9-mile point of the survey. A siphon crossing of the canyon is required. The location is practically at the mouth of the rugged part of the canyon. The line crosses obliquely and lands on the east side at the tapering point of the bench, which extends to the south. This is just above the right of way of the Oregon Short Line Railroad and the line continues on its east side. There is a large drop in the grade between the west-side and east-side canals.

The east-side country, extending to Ogden, was originally intended to be watered from the east canal of the Bear River Canal Company. The plan was never carried out, but at present nearly all the main body below the foothills from a point between Collinston and Deweyville to within 7 miles of Brigham City is covered by that canal.

On account of inadequate water supply and the exceedingly great difficulty in maintaining a safe canal through the very difficult sidehill country along the canyon and the valley next below, it is thought that a reclamation canal built along the bench above the steep slopes would serve this area far better than the existing canal. From the point where the latter reaches the foothills its location is such as to make it suitable for the water conveyer.

The lands in this area, especially around Brigham City, are probably the most valuable under the entire project when fully supplied with water.

SOUTHWESTERN CACHE VALLEY SECTION.

South of Bear River, on the west slope of Cache Valley, is a large area of land that is mostly dry-farmed at present. This is far above the river, which traverses the lowest part of the valley, and to reach it a siphon crossing of the river valley is required. The river, which is the outlet of Cache Valley, here runs westerly, cutting through the range that bounds the valley on the west side in the deep Bear River Canyon. From here to the south extremity of the valley is a distance of 15 to 20 miles. The drainage of this south part is to the north.

Cache Junction is only about 3 miles above the canyon, being on the south side of the river and at the junction of the Cache Valley branch with the main line of the Oregon Short Line Railroad.

The most practicable point for the siphon crossing of the river valley is between the high benches just above the rugged part of the canyon.

The survey starts at the 48.5-mile point of the main canal on the west side. First is the siphon crossing, the course of which is southeasterly. The horizontal length is 2,000 feet. The location is only about a half mile above the Bear River Canal Company's diversion dam, and the distance across the backwater here is about 350 feet. Outside of this, which is of little importance, the site is almost ideal for the purpose.

Referring elevations to the northwest end, the head above the water surface is 380 feet. The slopes of the benches are steep. For about 565 feet, horizontal length, the head is not less than 300 feet. On the southeast side the Oregon Short Line Railroad line is crossed. A fall of nearly 13 feet was given for the hydraulic grade line.

To the southeast, beyond the siphon, the line rounds the north end of the high bench or ridge and then runs southward on the same general course as the branch railroad. The country traversed has a considerable slope to the left of the line down to the flat where the railroad runs, so that the area above the latter averages not over about 1 mile wide, though the elevation averages over 300 feet less. Below the railroad is a wide strip of less desirable land, which merges with the wet, marshy land along the river bottoms.

The ground traversed by the canal survey is, in the main, not difficult for construction. Much the worse section is between the 4.7- and the 5.8-mile points, which includes about 3,400 feet where the use of anything but a flume would hardly be practicable. The range of hills here breaks off by a steep, rocky slope to the flat about 250 feet lower down. On each side of this section the ground is broken, but it soon opens out onto the cultivated bench lands. The town of Mendon is practically east of the 12-mile point and the center of Wellsville town is east of the 18-mile point. On reaching the main county road (between Wellsville and Brigham City) the line leaves the more or less broken country and passes through a fine, highly cultivated section, in which the expense for right of way would exceed the cost of constructing the canal. From here, at the 20.2-mile point, the line swings easterly, circling the southwest corner of the valley. The survey was ended at the 23-mile point, about 2½ or 3 miles east and 1 mile south of the center of Wellsville.

Beyond here, in the Hyrum neighborhood, the country is largely irrigated from Little Bear River.

It is estimated that not less than 15,000 acres of land could be watered from the branch, though not nearly all of this is choice land. Most of that north of Wellsville, reaching from the survey down to the foot of the main slope (200 to 250 feet lower) is on such a slope that the soil would be subject to wash in irrigating the land. The best land is below this slope but above the railroad. The flatter land next to the bottoms is liable to become alkaline.

The cost of the siphon crossing, with a maximum head such that only iron pipe will serve, would be a very large item in the expense of reaching the elevation of the surveyed line. On account of this and of the higher lands being subject to wash, and also of the fact that only a comparatively narrow strip of land (on such a slope) is gained by a great rise in elevation, it is probable that a line 150 to 250 feet lower would allow a much less cost per acre for reclamation than by keeping up to the highest limit possible, while 250 feet lower should miss about all the broken country. At a line only 50 feet lower the proportion of broken country would be much more than along the survey. Probably at least 150 feet lower is advisable if any drop at all is made.

The country in this section is well settled up, has excellent railway facilities, and is an important part of the well-developed Cache Valley.

The land should easily stand a cost of $40 per acre for water, an amount which would not be exceeded under the Bear Lake project.

The Portneuf diversion has been described with some detail because it is thought to be the most likely of the three main alternate diversion routes to be adopted. Under it are included all the bodies of the land practicable of reclamation.

The more important areas could, however, be irrigated from the lowest of the diversions.

GENTILE VALLEY DIVERSION.

This is the middle of the three diversions. The primary idea is to find a route into Cache Valley that would avoid construction through the long and rugged canyon of the river connecting Gentile Valley on the north with Cache Valley on the south. Such a route would, other things being equal, be decidedly preferable to the long roundabout one by way of the Portneuf. No diversion of the water into another drainage basin is required.

Gentile Valley is hemmed in by mountains on all but the north side.

The diversion over the range that separates it from Cache Valley is rendered possible by the Treasureton divide, which is a comparatively low saddle in the range, located at the southwest corner of Gentile Valley. The divide is rather broad and flat. A fork of Battle Creek heads on the south of it and Rocky Fork of Cottonwood Creek on the north. Its elevation is such that to cross it the river has to be tapped far back to the north. Gentile Valley extends about 15 miles north and south, and for all but the upper end the fall is so slight that little elevation can be gained. The lower end is 675 feet lower than the divide. North of the valley lies the high "tenmile" bench, before described. The river traverses this bench in a deep gorge cut in the lava formation and then enters the valley. From Soda Point to the head of this valley the fall is very heavy. The entire region extending from Chesterfield, 12 miles north of Bancroft, southward to the end of the valley at the canyon is practically one valley, but Gentile Valley is distinct in topography from the lava-bench portion.

The diversion over Treasureton divide requires a line running high up along the west side of Gentile Valley.

CANAL SURVEY.

The survey was started at the divide, it being the controlling point, and was run toward the river at a normal grade of 1.58 feet per mile. This grade was fixed so as to keep the line as much as possible on the main benches to the north. It gives a divide cut nearly a mile long, with a maximum depth of between 105 and 110 feet. Either the cut or a tunnel is necessary.

The country to the north for several miles is not specially unfavorable except for the crossing of Cottonwood Canyon, the south side of which is 2.8 miles from the summit. Cottonwood Creek is a stream heading not less than 20 miles back in the mountains to the northwest, and its canyon is so deep cut and rugged that a siphon crossing seems to be the only thing feasible. The horizontal length of this will be 1,750 feet and the actual length about 175 feet more. Its maximum head will be 314 feet and for 825 feet not less than 305 feet.

Northward from Cottonwood Creek there is a much longer proportion of broken country, requiring some expensive construction. There are sections of side-hill country with rock excavation and large ravines that cause detours and in a few cases are so deep cut that piping is needed. These and minor features tend to make the diversion rather a formidable undertaking.

At 28 miles is reached the south edge of Tenmile bench, which breaks off rapidly into the Gentile Valley, the section here being known as China Flat. The line is only 30 or 40 feet higher than the bench.

The line now circles around to the west and continues northward to the saddle described in discussing the Grace diversion. (See p. 520.) For all practical purposes this saddle fixes the maximum altitude allowable for Gentile Valley, as a grade contour higher than this would continue on northward around Portneuf Canyon.

The line swings easterly a little south of the saddle and gradually bears southeasterly, drawing near the river, which cuts southwesterly through the bench. The river is reached a few hundred feet above the " Tenmile " bridge at Grace, at the mouth of the upper section of the canyon before described. The distance from the summit of Treasureton divide by this route is 40.1 miles.

It is possible to save considerable in distance by locating the canal a little lower so as to avoid such a large detour to the north over the bench. To test this a line 20 feet lower down was run over the bench, leaving the river near the bridge. For the first 6 miles this line coincides with the lower route to the Portneuf.

This alternate survey was carried to where the grade began the ascent of the slope near the southwest corner of the bench and there ended; the line 20 feet higher serving practically for the continuation on to Treasureton divide. By its use 2.1 miles are saved, reducing the total length of the line to 38 miles. The country to the south at this level would not be materially different from that along the surveyed line.

As compared with the Portneuf route the main advantage of this route is its shortness. The main disadvantages are in not reaching the Marsh Valley area, in requiring a branch to reach even a part of the Bancroft area, and in having a larger proportion of its length through difficult country. Though apparently not so favorable as the Portneuf route, a careful estimate of cost and comparison of other features will have to be made before final choice is made.

From the Treasureton divide the water from the canal would be allowed to pass down the drainage of Battle Creek, a drop of 600 feet being required before reaching the required point of diversion for the lands in Cache Valley. The lower valleys would be reached just as from the Portneuf diversion.

CACHE VALLEY DIVERSION.

This is the lowest of the three main diversions. The primary idea is to divert the water over Cache Valley in the most direct way possible. Bear and Malad valleys can also be reached by this diversion.

To secure the elevation necessary for all but one of the Cache Valley bodies of land it is necessary to tap the river far above its level at the head of the valley.

The canyon connecting Gentile and Cache valleys is about 12 miles in length. Below it the river runs in a deep-cut channel between the high hills on either side. These hills soon taper out into the broad benches, the river continuing in a deep valley between them. This valley is nearly flat, of considerable width, and is bordered on either side by a steep slope, more or less broken by drainage channels that lead up to the top of the bench. The river does not come to near the surface of the surrounding country until many miles to the south. Then it flows sluggishly through the lower flat lands that lie in northern Utah.

To reach the areas lying in the north part of the valley west of the river requires a diversion at a level about 300 feet higher than the mouth of the canyon, which is 3 or 4 miles above the settlement of Riverdale.

There is only 260 feet fall through the canyon, so that its head lacks at least 40 feet of being at the required elevation, to secure which it will be necessary to go probably 8 or 10 miles farther up into Gentile Valley.

The descent in the river through here is exceedingly slow, and a canal grade would consume a large part of the elevation thus secured. A dam could be built near the head of the canyon, but this would flood a large area of farm land along each side of the river. In investigating this route a line was run entirely through the canyon. The length by this line is about 13 miles. For most of the way the canyon is rugged, and the construction of a conduit at the grade level required would be very expensive.

Some dam sites were surveyed to see if it were practicable to raise the water and so dispense with part of a canal, but the results were not encouraging.

The proposed canal of the Oneida irrigation district will take water from Mink Creek, a tributary of the Bear, emptying into the latter near the mouth of the canyon. This plan includes a siphon crossing the river at the mouth of the canyon, with an elevation at the north end of 300 feet above the river and at the south end of 270 feet. The reclamation canal should be about as high as this to reach all the land desired, and, if it were practicable, its location would be almost identical with that of the other.

The conclusion from the surveys was that the Cache Valley diversion is impracticable.

DIVERSION FOR CUB RIVER BENCH.

On the east side of Bear River, between it and Cub River and extending northward to a line north of Fairview, is a fine body of land that has a very insufficient water supply, derived mainly from

Cub River, part of whose water is used higher up. Its elevation is such that it is possible to cover it by a canal diverted from Bear River entirely below the canyon that connects the Gentile and Cache valleys.

To determine the practicability of this a survey was made, leaving the river shortly above the Riverdale highway bridge.

For the first 3 or 4 miles the ground is favorable for the construction of a safe channel. From there on the formation is a light clay, with some sand, which becomes very unstable when wet and slides and caves easily.

The line runs through this material for nearly 10 miles before reaching the top of the steep slope fronting the river. In a number of places there have been enormous slides through the action of percolating water. In some places the ground along the slope has broken away clear back to the edge of the bench. In others the grade runs along the face of the steep " cut " banks next to the river. The proportion of sand increases going southward and predominates after the first 5 miles, but the new material is worse than the clay in that water percolates through it so readily. At 13.2 miles from the head the grade reaches the top of the bench, where the first irrigable lands of consequence are encountered. Beyond here the line has to round a high sand ridge that runs parallel with the river before turning easterly across the main body of the land. This takes nearly 3 miles more. The material here is so sandy that trouble would be found in keeping a canal clear.

The land is mostly of good quality and comprises not less than 20,000 acres. On account of the treacherous character of the formation the canal would build through, however, it is thought that this diversion is not safe enough to be practicable.

A better plan would be to supply this land from the east side canal coming from Red Rock Pass after it reaches the Preston bench, as mentioned in description of such.

It is probable that the owners would be willing to stand a cost of $40 to $50 per acre for water.

STORAGE ON CACHE VALLEY STREAMS.

During the season the mountains east and south of Cache Valley were explored for storage reservoir possibilities by which the flood waters of the Logan, Blacksmith Fork, and Little Bear rivers could be retained for additional supply to the lower section of the project, but no basins worth considering were found on any of these streams.

WATER SUPPLY.

Detailed records of water supply have been kept throughout the year, and the available supply for storage in Bear Lake is given below. Results indicate a much greater supply than that for 1903, and subsequent records may serve as a basis for enlarging the outlines of the project beyond the possibilities mentioned in the Second Annual Report.

The following table shows the monthly discharge, in acre-feet, of Bear River at Dingle, Idaho, at point of diversion of the feeder canal into Bear Lake:

Discharge of Bear River at Dingle, Idaho, 1904, available for storage in Bear Lake.

Month.	Second-feet.		Acre-feet.
	Maximum.	Minimum.	Total.
January	350	145	17,250
February	2,020	350	29,680
March	2,265	615	66,280
April	1,450	615	67,620
May	3,230	1,365	154,360
June	3,230	1,190	140,570
July	1,100	390	47,120
August	490	265	19,840
September	310	265	16,750
October[a]	265	250	15,500
November[a]	300	250	18,000
December[a]	350	300	19,280
Total			612,550

[a] Estimated.

UINTA INDIAN RESERVATION.[a]

LOCATION AND PHYSICAL FEATURES.

The Uinta Indian Reservation is located in northeastern Utah, and was supposed to include the drainage basin of Duchesne and Uinta rivers. Surveys of the boundary line, however, have shown that a large area, including a considerable portion of the Deep Creek basin in the northeastern section and a large amount of territory south of and between the new southern boundary line and the summit of the ridge that divides the drainage basin of Duchesne River from that of Minnie Maud Creek, is outside of the reservation. Consequently the present area of the reservation does not wholly correspond with the river's drainage.

The reservation was set aside by Executive order of President Lincoln on October 3, 1861, and subsequently approved by the following acts of Congress: May 5, 1864, volume 13, page 63; September 1, 1887, and May 24, 1888, volume 25, page 167. It covers an area of 2,039,040 acres, or 3,186 square miles, being about two and one-half times the size of Rhode Island and one and one-half times the size of Delaware.

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[a] From report by Howard S. Reed.

Its northern boundary line is along the divide of the Uinta Mountains, which includes Mount Gilbert, whose elevation is 13,455 feet. Its western boundary is a portion of the Wasatch Range. Its southern boundary is a line considerably north of the divide between Duchesne River and Minnie Maud Creek, which ought to be its southern boundary, and in all probability would have been had the original idea of the limits of the reservation, which were defined as being the drainage basin of Duchesne River, been strictly adhered to.

Green River forms a portion of the boundary in the extreme southeast section, and the eastern boundary was subsequently changed by an act of Congress, approved May 24, 1888, in order to exclude a triangular area of 7,921.96 acres east of Fort Duchesne, upon which were found valuable deposits of uintaite, or "gilsonite." This excluded area contains some very fine agricultural land susceptible to irrigation and cultivation. The same is also true of the Deep Creek country.

The greatest due east-west length of the reservation is about 75 miles; the north-south width is approximately 60 miles.

DUCHESNE RIVER AND TRIBUTARIES.

The main stream is Duchesne River, which flows in an easterly direction through a fine agricultural valley, ranging from one-half mile to 2 miles in width.

The Duchesne has its source in the Uinta Range, and consequently drains a much more mountainous area than Strawberry Creek, thereby contributing a greater run-off per square mile on account of the proportionate increase in the precipitation, while the lower part of the drainage area of Strawberry Creek contributes practically nothing to the flow of the various streams except during the flood period.

The valley of Duchesne River from the mouth of Strawberry Creek down to Lake Creek averages 2 miles in width, and is bordered on either side by sandstone cliffs approximately 200 feet high.

The cliffs on the northern side are capped by a heavy deposit of coarse river gravel and cobblestones. Duchesne River is very crooked, swinging backward and forward across its valley, with its course marked by a thick line of cottonwood.

The main upper tributary of Duchesne River is Strawberry Creek, which drains an area of 1,166 square miles. This creek passes through what is known as Strawberry Valley, a fine tract of level land with an average elevation of 7,500 feet.

This elevation is rather high for general agricultural purposes, but is splendidly adapted to grazing, being well grassed and always assured of water, as the streams supplying the valley have their source in the Wasatch Mountains, whose canyons sometimes contain snow the year round.

For a number of years the Indians have leased this area and adjacent territory to cattle companies for grazing purposes, deriving therefrom a yearly income of $25,000. The area leased is approximately as follows:

Lands in Strawberry Valley and adjacent territory leased by Indians.

	Acres.
No. 1	280,000
No. 2	320,000
No. 3	100,000
Total	700,000

Currant and Red creeks, important tributaries to Strawberry Creek, drain the greater portion of the area between Duchesne River and Strawberry Creek. Red Creek is about 20 miles from Strawberry Valley; there is no water intervening except Currant Creek, about 3 miles west.

The hills for some distance east and west of Currant Creek are of red sandstone and the country to the east is generally undulating, sloping eastward to Red Creek. Blacktail Mountain, with an elevation of 10,000 feet, is 10 miles to the north, and Strawberry Creek Canyon is 7 miles in the opposite direction.

This portion of the country is well timbered with cedar and piñon pine, and the rock is sandstone of varying degrees of color and hardness.

East Creek, as appears on Geological Survey topographic maps, or Rock Creek, as it is known locally, empties into Duchesne River about midway between the forks of the Duchesne and Lake Creek. It is estimated that this stream carries approximately an amount of water equal to that of Lake Creek. Its drainage area is confined practically to the basin at its very head, which divides its waters between this stream and the East Fork of the Duchesne River.

After leaving this basin the confines of the stream bed are very limited, as it flows through practically a gorge approximately 18 miles in length, whose walls and slopes are very precipitous, thereby contributing very little to the flow of the stream except during the early spring, when the snows on its upper reaches are melting.

The country in and about this stream is used only for grazing, there being little or no land contiguous fit for general agricultural purposes.

Lake Creek is an important tributary of the Duchesne, draining the central portion of the reservation. Its source is on the southern slope of the Uinta Mountains and its flow is reenforced by lakes that exist at the very head of each branch. It flows in a southerly direction, entering Duchesne River about 3 miles above the so-called Price Road Bridge across the latter stream. Its drainage area at its mouth is 475 square miles.

Uinta River and its principal tributary, White Rocks River, drain the eastern portion of the reservation and adjacent area east of the reservation line. This area, however, is not very large, as it embraces only tracts that have been excluded by the various surveys of the eastern boundary line.

These streams have their sources in a series of lakes in the Uinta Mountains, which are helped out by the snow which exists the year round on the slopes and in the canyons, and warrants the assertion that a water supply here will be constant, with only such fluctuation as has been observed since the work was inaugurated here.

After emerging from their canyons 7 or 8 miles above the Indian agency at White Rocks they flow in a general southeasterly direction, uniting in various channels between the agency and the military post at Fort Duchesne. From this point they flow in one channel, entering Duchesne River 6 miles below, near the Ouray Indian School, at Leland, Utah.

To the north of the point where these rivers strike the low country south of the canyons the country is very mountainous and difficult of access, while to the south it is flat for some distance west of the rivers and has a distinct southern slope of about 40 feet to the mile.

Uinta River and various washes, however, have cut this country with a still greater slope of about 70 feet to the mile, and in the course of 5 to 7 miles below the canyons have cut the plateau into a number of mesas of varying widths.

As a result of the difference of the fall of the mesas and of the washes, cliffs from 150 to 200 feet in height border Duchesne River on the north side.

Immediately south of the river the bottom land is bordered by a similar line of cliffs, with a series of mesas extending southward for a number of miles.

Pole Creek is tributary to Uinta River from the east, entering a few hundred feet above the gaging station in the canyon of the latter stream. The area drained is limited in extent, being confined to a small valley between Uinta and White Rocks rivers. The source of this stream is as yet indefinite, as about 6 miles above the station it emerges from a good-sized cave, the extent of which is unknown. As is common with all these streams, its discharge is materially increased during the spring of the year, when it is probable that its maximum discharge may reach 75 to 100 second-feet; during the balance of the year its average discharge is between 10 and 15 second-feet. This, however, is constant.

Pole Creek Canyon in its lower reaches has very steep banks and the slope of the stream itself is very precipitous, thereby offering a situation for water-power development worthy of no little consideration.

Farm Creek is a small stream draining a limited area of 47 square miles at its mouth, between the Uinta and White Rocks rivers. During the irrigating season, and especially during the summer and early fall months, it contributes practically nothing to Uinta River, which it enters about 1½ miles above the Indian agency, its waters being all used by a few Indians who cultivate a small area within its basin. Except during the flood season it carries from 2 to 4 second-feet, while during the season of high water its maximum discharge may reach 40 second-feet. This, however, would be unusual and of very short duration.

Dry Gulch Creek has its source on the southern slope of the foothills of the Uinta Mountains, between Uinta River and Lake Creek. Excepting during the spring floods this creek for the greater part of its length is a dry wash, and would be for its entire distance did it not receive the waste waters from Canal No. 1 and Bench ditch, which it conveys to Uinta River, entering that stream about 1 mile above the Ouray Indian School. Of itself it contributes practically nothing to the water supply of the reservation, excepting during the period of high water, or for about a month in the spring.

Areas drained by Duchesne River and tributaries.

Stream.	Locality.	Area.
		Sq. miles.
Strawberry Creek	At mouth	1,166
Duchesne River	Above Strawberry Creek	703
Do	Above Lake Creek	2,247
Lake Creek, East Fork	At mouth	147
Lake Creek, West Fork	....do	160
Lake Creek	One-half mile below junction of two forks.	308
Do	At mouth	475
Duchesne River	At Price Road bridge	2,746
White Rock River	In canyon	114
Farm Creek	....do	47
Uinta River	....do	218
Do	At Fort Duchesne	672
Do	At Ouray Indian School	967
Dry Gulch Creek	At mouth	260
Duchesne River	....do	3,985

PRECIPITATION.

Rainfall records in this locality have been kept at Fort Duchesne and at Vernal, which is in the next valley, 28 miles to the east.

The average annual precipitation at Fort Duchesne from 1889 to 1903, inclusive, was 6.23 inches; at Vernal from 1895 to 1903, inclusive, it was 8.46 inches.

These records do not show the amount available for river supply, as none of the stations are located in the mountains, which are the source of the main supply. The Fort Duchesne record simply shows the rainfall (for the snowfall is of minor consideration) in that vicinity. The elevation is only 5,016 feet above sea level, Evanston datum, while the mountain peaks, whose elevation at places have altitudes of over 13,000 feet, receive without doubt a much larger precipitation than the country below, the snowfall being greatly in excess of the rainfall.

The following tables show the precipitation at Fort Duchesne and Vernal, Utah, for the periods mentioned:

Precipitation, in inches, at Fort Duchesne, Utah.

[Elevation, 5,016 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1889	0.35	0.18	0.32	0.68	0.73	0.15	0.49	0.56	0.34	0.66	0.05	1.77	5.28
1890	1.01	.27	.02	.21	.00	.00	1.35	.85	.32	1.17	.03	.27	5.50
1891	.22	.28	.57	.99	.96	.34	.24	1.42	1.46	.00	.00	1.06	7.54
1892	.40	.30	.78	1.24	1.35	.03	.16	.08	Tr.	.46	.14	.46	5.46
1893	.42	.44	3.10	2.01	.92	.00	.47	.57	.36	.16	.24	.49	9.18
1894	.08	.19	.56	Tr.	.20	.34	.26	.30	1.88	.34	.00	.69	4.84
1895	.09	.03	.09	.00	1.53	1.02	.17	.20	.03	.13	.90	.31	4.50
1896	.60	.09	.14	.21	1.40	.03	1.45	.64	2.23	.54	.20	.00	6.99
1897	.87	.90	.28	.01	.16	.02	.17	.21	4.61	3.00	.00	1.20	11.43
1898	.60	.10	.75	.17	.61	.45	.66	.66	.08	.05	.13	.10	4.36
1899	.20	.40	2.10	.60	.00	.05	.71	.90	.00	.83	.00	1.20	6.59
1900	.35	.00	.00	1.72	.15	.06	.08	.40	1.25	.27	.51	.30	5.09
1901	.25	.95	.15	.20	.60	.08	.14	2.47	.03	.64	.16	.51	6.18
1902	1.70	.05	.14	.70	.30	.50	.05	.00	1.45	.00	.00	.00	4.89
1903	.00	.80	.08	.00	1.02	.28	1.49	.20	1.20	.48	.00	.00	5.55

Mean for period from 1889 to 1903, 6.23 inches.

Precipitation, in inches, at Vernal, Utah.

[Elevation, 5,356 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1895	1.00	0.54	1.30	0.08	1.51	0.58	0.76	0.40	0.38	1.03	1.33	0.27	9.13
1896	.48	.29	.38	.89	.94	.04	1.86	.58	2.48	.69	.42	.04	9.09
1897	.96	1.11	.86	.58	.62	.23	1.08	.26	2.83	2.34	.42	1.20	12.49
1898	.63	.47	.60	.50	[a]2.03	.45	[a].34	.66	1.04	.30	.39	.17	7.58
1899	.40	.55	1.93	.39	......	.78	......	1.63	Tr.	......	......	......	8.41
1900	.47	.12	.15	2.00	.26	.14	.03	.22	1.46	.57	1.21	.04	6.67
1901	.71	1.36	.31	.33	.86	.21	.21	.73	.04	.42	.27	.48	5.93
1902	.21	.51	.86	.72	.42	.51	.12	.46	.99	.05	1.12	.97	6.94
1903	.39	.96	1.02	.67	1.30	.89	1.83	.13	1.50	.88	.18	.00	9.75

[a] Fort Duchesne record.

Mean for period from 1895 to 1903, 8.46 inches.

FORT DUCHESNE MILITARY RESERVATION.

The Fort Duchesne Military Reservation was established within the Uinta Reservation on September 3, 1887. The boundaries were defined as follows:

> Beginning at a point 2 miles due north of the flagstaff of Fort Duchesne, Utah Territory, and running thence due west 1 mile to the northwest corner; thence due south 3 miles to the southwest corner; thence due east 2 miles to the southeast corner; thence due north 3 miles to the northeast corner; thence due west 1 mile to the point of beginning.

It was provided that "the use and occupancy of the land in question be subject to such right, title, and interest as the Indians have in and to the same, and that it be vacated whenever the interest of the Indians shall require it upon notice to that effect to the Secretary of War."

Notwithstanding this proviso it is intended upon the opening of the reservation to settlement to retain this tract of land of 3,840 acres as a military post exempt from settlement.

The corners of the boundaries are marked with solid iron posts 5 feet long and 6 inches square. They are set 3 feet in the ground, having 2 feet exposed, marked appropriately.

At present there are stationed at Fort Duchesne 2 companies of infantry and 1 troop of cavalry, which with the civilian population makes a total of about 250 people, with 150 animals.

As two of the company barracks were burned in 1889, the original intention of making this a six-company post will probably never be carried out, so that at this time the present population is probably a maximum on which all estimates for water supply can be based.

The Government estimate for water supply for a military post is said to be 2 gallons per person per day and 5 gallons per animal per day. If this is correct, it is totally inadequate, for at the present time 8,000 gallons of water are used at the fort daily, although use is limited by the noncompletion of the sewer system. When this is finished, a daily supply of 10,000 gallons will, in the estimate of the quartermaster's department, be needed outside of that required for irrigation.

At the present time water for the use of the post is pumped directly from Uinta River into a tank, then distributed at the post through a complete water system. The water used for irrigation is furnished by a small ditch heading about one-half mile above the post. The amount required is small, as the acreage under cultivation is limited to the parade and the post garden. Probably 5 second-feet will be sufficient for all future needs for all purposes.

During the greater portion of the year the quality of the water is excellent, but during the spring and even after a rain it is very poor, as Deep Creek, which enters the Uinta 2 miles above the post, brings a vast amount of sediment.

MINERAL DEPOSITS.

Valuable deposits of coal are known to exist in different localities, but their extent is not known, as practically no work has ever been done except in Deep Creek.

Gilsonite is found in various places, both on this reservation and on the old Uncompahgre Reservation, but no work has ever been done on any of the claims excepting a vein at Fort Duchesne, the discovery of which was the cause of the so-called "strip" being purchased from the Indians and thrown open to settlement by act of Congress approved May 24, 1888.

The Parriette mine is the only one, other than the strip vein, that has been operated in this locality. This latter is just across the southern boundary, and there is some doubt as to its correct location.

Elaterite is mined in the southwestern corner of the reservation at the head of Indian Canyon, under a lease held by the Raven Mining Company from the Indians; about 150 tons are excavated monthly.

Other known materials of an asphaltic nature within the confines of the reservation are wurtzilite, ozocerite, petroleum deposits, and coal. This condition prevails throughout this entire northeastern section of the State, the country around about Vernal also being very rich, especially in uintaite or gilsonite, in coal, and in sand asphaltum, which extends to and beyond the Colorado boundary, where some of the richest veins are worked at the present time.

A report in great detail on these deposits by George H. Eldridge, geologist, was published in the Twenty-second Annual Report of the United States Geological Survey, part 1, pages 330–364.

The existence of other minerals in sufficient quantities for successful mining is as yet somewhat in doubt. The Florence Mining Company, organized especially for exploiting the mineral deposits of the reservation, has had a party of experts at work all summer thoroughly examining every known locality where mineral of any nature was said to exist. As yet they have met with but indifferent success, leading to the belief that except for the hydrocarbons (which are abundant) mining possibilities within the present reservation boundaries are slight.

Mining, cattle, and other leases from the Indians, held by outside parties, will be raised upon the opening of the reservation. Those holding mining leases, the Raven Mining Company and the Florence Mining Company, receive for the cancellation of their leases the privilege of locating and holding, prior to the reservation being thrown open, a certain number of mining claims, limited in the case of the Raven company to 100 hydrocarbon claims, and to the Florence company of 640 acres, all in one lot, of mineral claims, such as gold, silver, copper, etc.

ALLOTMENTS OF LANDS TO INDIANS.

UINTA AND WHITE RIVER UTES.

At the Uinta Reservation it has been the custom of the Indian agents, especially of the last one, H. P. Myton, to allot to Indians such lands as they might select and to give them all the encouragement possible, both materially and otherwise, to cultivate them. Their efforts in these directions have met with good success.

The total extent of the allotted lands is approximately 6,240 acres, and will be much greater when all allotments are made. The policy will probably be to increase the Indians' holdings in the same locality as their present farms are situated, for the present area cultivated by each family is comparatively small to what it will be when each member of the family receives his or her respective allotment.

The following is an extract from a letter of the acting Indian agent, relative to the number of Indians on the Uinta and White River allotment roll:

> There are 468 Uinta Utes, of whom 159 are adult males and entitled to 80 acres each; and others who will receive only 40 acres, except in the case of widows—heads of families—who will also receive 80 acres. These widows number about 68.
>
> There are 365 White River Utes, 121 of whom are adult males and about 66 widows, heads of families.

On this basis allotments will have to be made as follows:

Allotments of lands to Uinta and White River Utes.

	Acres.
UINTA.	
227 heads of families, at 80 acres each	18, 160
241 other individuals, at 40 acres each	9, 640
WHITE RIVER.	
187 heads of families, at 80 acres each	14, 960
178 other individuals, at 40 acres each	7, 120
Total	49,880

It is further provided that the Indians shall receive 250,000 acres of grazing land south of Strawberry Creek.

ALLOTMENT TO UNCOMPAHGRE UTES.

By act of Congress approved June 9, 1897, the President was authorized to appoint a commission to allot land to the Uncompahgre Indians and to treat with them for opening the remainder of their reservation.

These Indians were originally settled upon a reservation in Colorado, but were moved to Utah in 1881. As a compensation for their removal they were to receive the proceeds of the sale of all the lands of their original reservation.

For this reason the act above referred to required the Uncompahgres to pay for their allotments at the rate of $1.25 per acre from the proceeds of sales of their reservation in Colorado.

The greater proportion of the old Uncompahgre Indian Reservation in Utah is a desert not susceptible of irrigation, the only land adapted for this purpose lying among the bottom lands bordering Green and White rivers, an area not sufficient for the needs of the Indians.

For this reason a second commission was appointed to treat with the Uinta Indians for the sale of certain of their lands along Duchesne River for the purpose of placing the Uncompahgres on them.

This latter commission came to an agreement with the Uinta Indians, and 550 Uncompahgre Utes were given land on the Uinta Indian Reservation, principally along Duchesne River, in 295 allotments, making use of a total of 44,349 acres. At $1.25 per acre this amounts to $55,436, which amount was paid January, 1903, by the Uncompahgre Indians to the Uintas.

Each head of family received 160 acres of irrigable land, with 160 additional acres for grazing purposes. Each single person over 18 years of age received 80 acres of irrigable land, with 80 acres for grazing purposes. Each orphan under 18 years of age received 80 acres of irrigable land, with 80 acres for grazing purposes. Each other person under 18 years of age born prior to the allotment received 80 acres of irrigable land, with the same amount for grazing purposes. Thirty-two miscellaneous allotments were made on the bottom lands of streams tributary to Green and White rivers. All allotments were made subject to ratification by Congress.

The commission did not have sufficient time to settle all of the Uncompahgres on lands, so that at the present time about 200 of these Indians are unprovided for. The present allotments along the Duchesne extend to above Lake Creek, and the Uintas have objected to a further extension in that direction; consequently it is something of a problem where they will be settled. There is under existing conditions no more available land on Green and White rivers, and it may be the best plan to locate them upon the Uinta Indian Reservation, regardless of whether any more money is paid to the Indians of this reservation for the land or not.

The law requires that they shall be given agricultural lands, and it may be best to locate them on the bottom lands farther up Duchesne River and Lake Creek, or else place them in some locality where they could receive some benefit from the existing canals, which, if necessary, could easily be enlarged to meet added demands on their water supply.

The following tables show the amount of land already allotted to the Uncompahgre Indians, of which they are the owners pure and simple. Serious consideration will have to be given to the water supply of these holdings before much settlement is permitted from the outside:

Allotments to the Uncompahgre Utes on the Uinta Indian Reservation, Utah.

	Acres.
T. 2 S., R. 1 E	603. 19
T. 2 S., R. 2 E	621. 45
T. 3 S., R. 1 E	8, 040. 78
T. 3 S., R. 2 E	4, 744. 64
T. 4 S., R. 2 E	2, 003. 88
T. 4 S., R. 3 E	847. 96
T. 5 S., R. 3 E	589. 35
T. 3 S., R. 1 W	7, 568. 61
T. 3 S., R. 2 W	8, 355. 41
T. 3 S., R. 3 W	7, 557. 23
T. 4 S., R. 2 W	1, 282. 39
T. 4 S., R. 3 E	2, 133. 88
Total	44, 348. 77

Allotments to Uncompahgre Utes outside the reservation.

	Acres.
T. 6 S., R. 22 E	731. 89
T. 8 S., R. 20 E	3, 820. 55
T. 8 S., R. 21 E	1, 673. 90
T. 8 S., R. 22 E	74. 80
T. 9 S., R. 19 E	279. 90
T. 9 S., R. 20 E	1, 486. 22
T. 9 S., R. 21 E	2, 682. 51
T. 9 S., R. 22 E	1, 038. 33
T. 10 S., R. 20 E	1, 000. 00
Total	12, 788. 10

Miscellaneous allotments to Uncompahgre Indians.

	Acres.
Willow Creek allotments, Nos. 1–12, inclusive, and 15, 28, and 29	1, 353. 88
Hill Creek allotments, Nos. 13–14	173. 98
White River and Wagon Ax Canyon allotment, No. 19	38. 05
White River allotment, Nos. 16, 20, 21, 22, 23, and 31	754. 97
Bitter Creek allotment, Nos. 17, 18, 24, 25, 27, and 30	858. 65
Upper Sweet Water Creek allotment, No. 26	60. 00
Sweet Water Creek allotment, No. 32	72. 45
Total	3, 311. 98

Total lands of Uncompahgre Indians.

	Acres.
On the Uinta Indian Reservation	44, 348. 77
Outside, on Green and White rivers	12, 788. 10
Miscellaneous allotments	3, 311. 98
Total	60, 448. 85

SUMMARY OF LANDS NECESSARY.

Lands necessary to carry out the provisions of the act and to provide for the future needs of the Uncompahgres not yet allotted.

	Acres.
Uinta and White River Utes, irrigable land	49, 880
Uinta and White River Utes, grazing land	250, 000
Uncompahgre Utes, irrigable land	9, 760
Total	309, 640

As the 250,000 acres above is already provided for specifically, it is only necessary to consider the other items, of which, in the nature of things, the 49,880 is the most important.

NUMBER OF INDIANS ON THE RESERVATION.

UNCOMPAHGRE UTES.

The Indian Office census for 1902 and 1903 gave the following numbers of Uncompahgre Ute Indians:

Uncompahgre Utes on Uinta Indian Reservation.

1902.	
Males over 18 years of age	287
Females over 18 years of age	264
Males 6 to 18 years of age	87
Females 6 to 18 years of age	32
Males under 6 years of age	32
Females under 6 years of age	31
Total for 1902	795

1903.	
Males over 18 years of age	255
Females over 14 years of age	257
Males under 18 years of age	80
Females under 14 years of age	72
Total for 1903	664

Of these, 550 have been allotted lands, leaving 114 to be taken care of, minus those born subsequent to the allotments.

Notwithstanding the fact that the preceding figures were given and have been used as official figures, a very careful camp to camp census has just been completed by an especially competent man. This is being tabulated for use in allotment work, and it shows that there are at present only 555 Uncompahgre Ute Indians, of which number 360 only, as per the original allotment roll, received 295 allotments, and are considered at the present time as holding the entire amount of land previously allotted, viz, 60,448.85 acres.

This recent work and the provision of the law that provides that "all allotments hereafter made to Uncompahgre Indians of lands in said Uinta Indian Reservation shall be confined to agricultural lands which can be irrigated, and shall be on the basis of 80 acres to each head of family and 40 acres to each other Indian and no more," necessitates a considerable modification of previous estimates as to the amount of land necessary to satisfy the needs of this tribe. Consequently 195 Uncompahgre Indians yet unprovided for will need, assuming that four individuals constitute a family, the following acreage:

Lands required for allotments to Uncompahgre Utes.

	Acres.
49 heads of families, at 80 acres each	3,920
146 other individuals, at 40 acres each	5,840
Total	9,760

UINTA AND WHITE RIVER UTES.

The census of 1902 and 1903 gave the following figures as to the number of the Uinta and White River Utes on the reservation June 30 of those years:

Uinta and White River Utes on Uinta Indian Reservation.

UINTAS.

1902.

Males over 18 years of age	163
Females over 18 years of age	122
Males 6 to 18 years of age	54
Females 6 to 18 years of age	43
Males under 6 years of age	38
Females under 6 years of age	47
Total for 1902	467

1903.

Males over 18 years of age	154
Females over 14 years of age	134
Males under 18 years of age	93
Females under 14 years of age	71
Total for 1903	452

WHITE RIVER UTES.

1902.

Males over 18 years of age	116
Females over 18 years of age	96
Males 6 to 18 years of age	49
Females 6 to 18 years of age	54
Males under 6 years of age	25
Females under 6 years of age	25
Total for 1902	365

1903.

Males over 18 years of age	121
Females over 14 years of age	99
Males under 18 years of age	73
Females under 14 years of age	63
Total for 1903	356

This makes a total of 808 Indians to whom lands will have to be allotted previous to the throwing open to settlement of the lands of this reservation.

CONDITION OF THE INDIANS.

As indicative of the constant advancement of the Indians, the following tables are submitted:

Source of subsistence in 1898 and 1902.

	1898.	1902.
	Per cent.	*Per cent.*
Indian labor	20	40
Hunting and fishing	10	7
Government rations	65	33
Cash annuity	5	10
Lease money	....	10

The two items emphasizing more than anything else their advancement toward civilization are the notable decreases in the amount of rations issued and the increase in labor rendered. The agent has informed me that a further cut in the rations of 50 per cent has been made this year, 1903, the amount thus saved being expended in labor.

Other items of interest are: Births during 1902, 50; deaths during 1902, 76. From this showing these Indians are not holding their own.

The following table from the report of the Indian Commissioner for 1902 shows the products and results of Indian labor during that year:

Products of Indian labor and industry for 1902 and 1903.

	1902.	1903.
Land:		
Cultivated during year by Indians ... acres	5,180	5,202
Broken during year ... do	250	130
Fence—		
Acres under	70,000	70,000
Made during year ... rods	1,400	600
Families actually living upon and cultivating lands allotted in severalty	65	65
Crops raised during year:		
Wheat ... bushels	2,740	3,000
Oats, barley, and rye ... do	23,000	[a] 12,000
Corn ... do	1,300	....
Vegetables ... do	3,651	[a] 2,536
Hay ... tons	3,170	3,000
Butter made ... pounds	2,000	[a] 700

[a] Figures too high last year.

Products of Indian labor and industry for 1902 and 1903—Continued.

	1902.	1903.
Miscellaneous products of Indian labor:		
Lumber, sawed .... M feet..	267	65
Lumber, marketed .... do....	([a])	([a])
Wood, cut .... cords..	524	620
Freight transported by Indian teams—		
Quantity .... M pounds..	592	197
Earned by freighting	$9,343.00	$3,940.00
Value of product of Indian labor disposed of—		
To the Government	$5,705.00	$2,513.00
Otherwise	$4,000.00	$3,870.00
Stock owned by Indians:		
Horses, mules, and burros	14,130	1,494
Cattle	3,300	1,700
Swine	70	65
Sheep	4,700	1,100
Goats	120	70
Domestic fowls	1,200	900
Roads:		
Made .... miles..	....	....
Repaired .... do....	55	....
Days of labor by Indians	446	400

[a] All used at agency and in the construction of dwelling houses.

The Uintas are more progressive than the White River Utes and are really anxious to have and own their own farms. Had it not been for their influence and their good work the consent of the Indians to opening the reservation would never have been obtained.

The greater portion of both the Uinta and White River Indians are located in the immediate vicinity of the agency, and it is safe to say that their selections of land will be in that locality.

EXISTING CANAL SYSTEMS.

A number of canals have been constructed on the reservation by the Government for the Indians. For convenience of arrangement and designation they will be taken up as they succeed each other south of the agency, numbering them accordingly.

The first canal is the so-called agency ditch, heading a short distance above the agency and taking water from the extreme western branch of White Rocks River. This ditch was built exclusively for, and supplies only, the agency with water for domestic uses and for what few gardens are planted there. Its maximum capacity is probably about 10 to 15 second-feet, but as the need of water is limited it is regulated so that 5 second-feet is about all the ditch has ever carried.

The second canal is known as canal No. 1. It heads about 1½ miles southwest of the agency and is intended to furnish water to Indian farms located along the mesa (which is extensive in size) and to the Government farm about 15 miles to the southwest.

After reaching the fifth mile of its length the water was originally permitted to tumble over a very steep cliff and to find its way into its natural channel until the ninth mile was reached, when it was taken again into an artificial channel. More recently, however, just before reaching the 5-mile mark an artificial channel has been constructed at right angles to the main ditch, and the water is conveyed for some distance along a spur of the mesa doing duty on some farms situated there; then it is allowed to seek its natural channel below, eventually getting into the artificial channel at the 9-mile post as before.

After leaving the mesa the land through which the canal passes is a fine sandy loam very susceptible to erosion; consequently the lower reaches are very much eroded, and the surplus water, which eventually finds its way into the Uinta River through Dry Gulch Creek, is very heavily charged with sediment.

The third, or "Bench," ditch heads in the same extreme western branch of Uinta River, about 5 miles south of the agency, in sec. 18, T. 1 S., R. 1 E., of the Uinta special meridian, and runs almost due south for about 8 miles, furnishing in this distance water for the most attractive and best cultivated portion of the entire reservation, generally known as "The Bench." Here about 1,000 acres of land are cultivated by the Indians in adjoining farms, which during the season present a very pretty sight, and besides are very instructive as an illustration of what can be done here by well-directed efforts.

The maximum capacity of this canal is approximately 75 second-feet.

At the extreme southern end of the bench the surplus water of this canal tumbles over the edge of the cliff, which is about 200 feet high, and, as in canal No. 1, eventually finds its way through Dry Gulch Creek to Uinta River. The grade of these channels through the Dry Gulch country is very steep, and as the soil is easily eroded each one contributes its share of sediment to the main stream, making the Uinta below these sections very turbid.

A canal was constructed heading on Dry Gulch Creek at the Price road crossing, with the intention of taking this heavily charged water and diverting it to the adjacent levels between the Uinta and Duchesne rivers; but the ditch soon filled with sediment and is now worthless

The fourth canal heads on the Uinta about 1 mile south of Fort Duchesne and furnishes water for the farms on the east side of Uinta River between Fort Duchesne and its junction with Duchesne River 6 miles below. Its capacity is approximately 15 second-feet.

The fifth canal takes its water from the right bank of the Duchesne in sec. 5, T. 4 S., R. 3 W., and follows the general line of the river itself, watering the lands lying between the river and the cliffs.

This canal extends to and slightly beyond the Government farm (which up to the present time has been operated at the Price Road Bridge across the Duchesne) and is about 12 miles in length. Although no measurements have been made, its maximum capacity is estimated at about 25 second-feet, with ample opportunity for enlargement to whatever capacity may be necessary to cover all these bottom lands, which are already within the allotted portion of the reservation.

The sixth canal receives its water from the Duchesne about 8 miles northwest of the Ouray Indian School and irrigates the land lying in the triangle between Uinta and Duchesne rivers in the vicinity of the school.

The school depends upon this ditch for its water for irrigation purposes, but its domestic supply is furnished by a complete waterworks system, installed this year, consisting of a good-sized tank, into which water is pumped from the Uinta River by a gasoline engine and then distributed by a system of pipes throughout the school buildings and grounds.

Several small ditches divert water from the Duchesne below the school to irrigate the lands occupied by the Uncompahgre Indians. The White River Indians have a few ditches, little more than furrows, to convey water to their lands east of the agency at White Rocks.

None of these canals at the present time is large enough to furnish sufficient water for the contiguous territory, but all are desirably located and are susceptible of enlargement to almost any capacity needed. They should, therefore, receive a good deal of consideration when any comprehensive scheme of irrigation on this reservation is taken under advisement.

PRESENT DIVERSIONS OF WATER FROM THE RESERVATION.

At the present time and for a number of years water has been diverted from certain tributaries on upper Strawberry Creek, carried across the divide, and turned into Daniels Creek, whence it finds its way downward and is again diverted and used on lands in the vicinity of Heber. There are three diversion ditches—Strawberry ditch, Willow Creek ditch, and Hobble Creek ditch—with capacities of 200, 60, and 50 miner's inches, respectively. The diversions were made by white settlers in Daniels Creek Valley without the consent or authorization of the Indian agent or of the Department of the Interior.

AGRICULTURAL AREAS.

The agricultural area may be divided into four sections, each of which lies under the river flowing through it. Uinta and White Rocks rivers are practically one after leaving their canyons, but as they will be considered in this report as being able to furnish water to distinct districts they will be considered separately. From that view point the country will be divided into the Uinta River, White Rocks River, Lake Creek, and Duchesne River agricultural areas, and it will be considered that the lands of the reservation will be so divided that they will be irrigated from these individual rivers to their best advantage.

UINTA RIVER AGRICULTURAL AREA.

The area that could most advantageously be watered from the Uinta River is as follows:

Agricultural areas under Uinta River.

	Acres.
T. 1 N., R. 1 W., secs. 7–36, inclusive	19, 200
T. 1 S., R. 1 W., secs. 1, 2, 3, 4, 9, 10, 11, 12, 13, 14, 15, 16, 22, 23, 24, 25, 26, 28, ½ of 29, ½ of 32, 33, ½ of 34, and 36	13, 440
T. 1 S., R. 1 E., secs. 6, 7, 18, 19, 20, 21, 28–34, inclusive	8, 320
T. 2 S., R. 1 W., secs. 2, 3, ½ of 4, all of 5, 6, 7, 8, 10–36, inclusive	21, 120
T. 2 S., R. 1 E., secs. 3–10, inclusive, 15–22, inclusive, ½ of 23, ½ of 26, all of 27–35	16, 640
T. 3 S., R. 1 W., secs. 1, 2, 3, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	8, 320
T. 3 S., R. 1 E., secs. 3–18, inclusive, 21, ½ of 22, ½ of 23, ½ of 24	11, 820
T. 3 S., R. 2 E., secs. 7, ½ of 8, all 15, 16, 17, and 18	3, 520
Total	102, 380

Much of this area is not first-class land, and some of it, especially the greater portion of T. 1 N., R. 1 W., is rather rocky, but some farms are already located there, a few of which get water from canal No. 1, others from their own ditches.

The cultivated area of these farms produces good crops, and it seems that it is only necessary to apply water to most any portion of this land to get good results.

This summary has included all land to the west of Uinta River as far as the bluffs bordering the Dry Gulch country and south to and including all land north of Duchesne River to where Uinta and Duchesne rivers join. This territory could be best covered by the extension both in size and length of Canal No. 1 and the Bench ditch which, owing to the slope of this country, are so situated as to do this service economically. A good portion of this land is unfit for cultivation, but this is of little consequence, for there is not enough water in Uinta River to supply all the land, even if the water were stored and used only during the irrigation season. If 75 per cent is worth reclaiming—and it is, at a conservative estimate—that is enough to take the entire supply of Uinta River.

This area contains the greater part of the cultivated land of the reservation, and probably the majority of the allotments will be located here. It is better situated than any other for two reasons: It has the agency on the north almost at hand and the military post below, where all products, especially hay and grain, can be disposed of. Due north of the post is an area of approximately 6,000 acres of some of the very best land on the reservation.

WHITE ROCKS RIVER AGRICULTURAL AREA.

As Uinta River is assumed to cover all the good land to the west, so White Rocks River is expected to irrigate all good land to the east; the small area between the two from the foothills to within 2 or 3 miles of the agency is rather poor and hardly fit for cultivation at all, as it is very rocky and covered with a growth of scrub cedars. Some of it is farmed with water from Farm Creek, but the supply is very limited. The needs of this area are so limited that they are hardly worth considering.

The land that White Rocks River would cover is practically limited to the following on the reservation:

Agricultural areas under White Rocks River.

	Acres.
T. 1 N., R. 1 E., secs. 5–8, inclusive; 17–22, inclusive; 27–36, inclusive	12,800
T. 1 S., R. 1 E., secs 1–5, inclusive; 8–17, inclusive; 22–27, inclusive; 35 and 36	14,720
T. 2 S., R. 1 E., secs. 1, 2, 11–14, inclusive; ½ of 23 and all of 24 and 36	5,440
T. 3 S., R. 1 E., secs. 1 and 2	1,280
Total	34,240

Accepting 75 per cent of this area as good irrigable land, would give about 25,680 acres.

Working on the basis that all the water of White Rocks River was to be conserved and used as needed, this amount of irrigable land would not use up the available water supply, which is a very good thing, as lying directly east of the reservation boundary line is the so-called "strip" referred to on page 539.

This contains about 7,000 acres of very good land, and it would not be difficult to extend a canal so as to cover this land and the area beyond to the south to the triangle formed by Duchesne and Green rivers. This last area lies in a series of large benches, and it is estimated that it contains from 20,000 to 60,000 acres.

Several attempts have been made to get water to this territory.

The first attempt was made by Messrs. McConnall, Carter, et al., in 1890 or 1891. A company, whose correct name is unknown, was incorporated and, it is understood, is in existence to this day and holds its right of way. The second attempt was made by Walker Brothers, of Salt Lake City. They organized but did not incorporate, though they actually made a survey for a canal line.

As both these companies had as an objective point the placing of water on the same land, their point of starting from White Rocks River was necessarily the same, and the general contour of the country followed was identical with each.

Their scheme is perfectly feasible, and probably no better disposition of the water of White Rocks River could be made than by following out this outline. It would cover some excellent land on the reservation on the first bench after leaving the river, and upon leaving that would go through the Deep Creek country, skirting the foothills, and covering all of that land which is particularly good. This latter locality alone approximates 16,000 acres.

In this discussion the water of both these rivers is assumed to be conserved and its entire supply available. The construction of reservoirs in the canyons is perfectly feasible.

LAKE CREEK AGRICULTURAL AREA.

The land directly tributary to Lake Creek is as distinct as that lying under Uinta and White Rocks rivers, and can be practically divided into the following sections:

(1) The section below the junction of the two forks down to and including sec. 20, T. 3 S., R. 3 W., comprising approximately 18,000 acres.

(2) The section almost adjoining this and extending to the land estimated to be under the Uinta drainage, or to the edge of the Dry Gulch country, comprising approximately 12,000 acres.

(3) The section north and east of the Duchesne, adjoining that under the Uinta drainage and connecting with the Dry Gulch Creek country, and containing approximating 7,680 acres. These three are all on the east side of the river. The first two are bench lands and the third is the low, level, flat country under these benches, extending to the very edge of Duchesne River and Lake Creek on the east and as far north as sec. 12, T. 2 S., R. 3 W.

(4) The section embracing the land on the west side of Lake Creek and extending to the very point of the triangle formed by the junction of Lake Creek and Duchesne River, comprising an area of approximately 19,840 acres.

Altogether the following area is tributary to Lake Creek:

Agricultural areas under Lake Creek.

	Acres.
Section 1	18,000
Section 2	12,000
Section 3	7,680
Section 4	19,840
Total	57,520

Of this, 8,960 acres have already been allotted to the Uncompahgre Indians, who have made no attempt to cultivate more than 1 square mile of it. However, the failure of the Government to furnish water for this area has something to do with this condition of things.

DUCHESNE RIVER AGRICULTURAL AREA.

Owing to the altitude of the land above the junction of Duchesne River and Strawberry Creek it is not as well adapted to general agricultural purposes as to grazing; therefore in this discussion only the land lying below Strawberry Creek on the south or right bank will be considered, all the land on the upper side of the river having already been taken care of.

The law provides that 250,000 acres of land south of Strawberry Creek shall be reserved for the use of the Indians for grazing purposes. Whether or not that will be confined to the present limits of the reservation is at present undecided, but should that prevail all the land south of Strawberry Creek and west of Indian Canyon will be appropriated to satisfy this provision of the law, precluding from consideration all irrigable land west of Indian Canyon and confining this discussion to the land lying east of Indian Canyon and south of Duchesne River.

West of Antelope Creek the land is not particularly well adapted to irrigation, owing to its being considerably cut up by side canyons and dry washes. To the east this condition does not prevail, and there exists in that section an area of very good land between the river and the cliffs bordering these bottom lands and extending to range 1 east. As the territory on the other side of the river is placed in and under the Uinta drainage, it would perhaps be more economical to irrigate this small section east of the Uinta special meridian from the canal watering the land lying between Uinta and Duchesne rivers, or else from a canal on the bench lands above. As it is small in area, it will not demand much consideration.

Leaving this area out of consideration there remain approximately 11,500 acres of bottom lands, of which approximately 10,500 acres have already been allotted. A canal already in operation covers the greater part of this area, but is totally inadequate to supply the entire area. It could, however, be enlarged sufficiently at not a great expense to cover these bottom lands. It heads about 1½ miles above Antelope Canyon, receiving its water from Duchesne River, and extends to and ends in sec. 32, T. 3 S., R. 1 W.

A second area that could be irrigated from the Duchesne at about Antelope Canyon extends westward to and beyond the bench country to the Sixmile Draw, so called. It comprises 21,800 acres, 8,000 of which are bench proper, and the other 13,800 within the Sixmile Draw.

A third area is the bench in the southeastern corner of the reservation immediately west of lower Duchesne River, at and below its junction with Uinta River. This territory could be irrigated from the upper canal. It is said to contain 21,900 acres.

A fourth area to be irrigated from Duchesne River would be a small amount of land that could be provided for by an extension of the upper canal or by a branch from any other of the canals watering the country to the north. It consists of the bottom lands of the lower Duchesne, upon which some Uncompahgres are at present situated by allotment. It may contain 10,000 acres of good land.

All these lands lie exceedingly well for irrigation, especially the lower lands below the benches, the principal problem being only to make a choice of the various routes by which water can be put on them most economically.

A number of canal lines were run, especially along Duchesne River, by C. C. Babb and A. L. Fellows in 1899, 1900, and 1901, while the survey of the agricultural lands of the reservation was being carried on by Mr. Babb. These he describes in great detail in his report of his work, entitled "The Water Supply of the Uinta Indian Reservation, Utah," pages 40–44. These canals perhaps would have to be modified to quite an extent should consideration be given to the possible construction of reservoirs on the different streams. There are said to be good reservoir sites on both upper Duchesne River and Lake Creek, though what would answer perfectly as a reservoir site in the estimation of the average inhabitant is apt to dwindle to exceedingly small proportions when instruments are used and actual capacities determined.

SUMMARY OF AGRICULTURAL AREAS.

Summary of land susceptible of irrigation both on and off the reservation.

		Acres.
Uinta River area:		
All on reservation		102, 380
White Rocks area:		
On reservation	34, 240	
Strip area	7, 000	
Green River area	21, 200	
		62, 440
Lake Creek area:		
On reservation		57, 520
Duchesne River area:		
Area No. 1	11, 500	
Area No. 2	8, 000	
Sixmile Draw	13, 800	
Area No. 3	21, 900	
Area No. 4	10, 000	
		65, 200
Total		287, 540

If 25 per cent is deducted from the Uinta River and White Rocks area, there remains the following:

Net lands susceptible of irrigation.

	Acres.
Uinta River area, 102,380, less 25 per cent	76, 785
White Rocks area, 62,440, less 25 per cent	46, 830
Lake Creek area	57, 520
Duchesne River area	65, 200
Total	246, 335

This is subject to change, but is the result of a very conservative estimate, and instead of being reduced by more extended information will probably be increased quite materially, even beyond the available water supply.

WATER SUPPLY.

Observations on the water supply of the reservation have been carried on since the fall of 1899. As these years have been average ones, it is believed that estimates for succeeding years can be based on them, with the assurance that they will be correct.

The following tables show what the water supply has been:

UINTA RIVER.

Estimated mean monthly discharge of Uinta River at Canyon station.

[Drainage area, 218 square miles.]

Month.	Discharge in second-feet.	Total in acre-feet.	Run-off. Second-feet per square mile.	Run-off. Depth in inches.
1899.				
September	165	9,818	0.73	0.81
October	162	9,961	.72	.83
November	130	7,736	.58	.64
December	120	7,379	.53	.61
1900.				
January	112	6,887	.51	.59
February	112	6,220	.51	.53
March	125	7,686	.57	.66
April	138	8,212	.63	.70
May	650	39,967	2.98	3.44
June	597	35,524	2.74	3.06
July	223	13,712	1.02	1.18
August	184	11,314	.84	.97
September	157	9,342	.72	.80
October	154	9,469	.71	.82
November	138	8,212	.63	.70
December	145	8,916	.67	.77
The year	228	165,461	1.04	14.22
1901.				
January	140	8,608	.64	.74
February	140	7,775	.64	.67
March	150	9,223	.69	.80
April	179	10,651	.82	.92
May	684	42,058	3.14	3.62
June	355	21,124	1.63	1.82
July	251	15,433	1.15	1.33
August	242	14,880	1.11	1.28
September	193	11,484	.89	.99
October	163	10,022	.75	.86
November	142	8,450	.65	.73
December	147	9,039	.67	.77
The year	232	168,747	1.07	14.53

Estimated mean monthly discharge of Uinta River at Canyon station—Continued.

Month.	Discharge in second-feet.	Total in acre-feet.	Run-off.	
			Second-feet per square mile.	Depth in inches.
1902.				
January	136	8,360	0.62	0.71
February	127	7,083	.58	.60
March	144	8,837	.66	.76
April	154	9,164	.71	.79
May	555	34,114	2.55	2.94
June	665	39,579	3.05	3.40
July	262	16,132	1.20	1.38
August	181	11,144	.83	.96
September	167	9,923	.77	.86
October	152	9,364	.70	.81
November	139	8,269	.64	.71
December	125	7,686	.57	.66
The year	235	169,655	1.07	14.58

The discharge for 1903 was 185,540 acre-feet.

The preceding tables show an average yearly discharge of 172,350 acre-feet, which is probably a fair average for any period of years. This would furnish water sufficient for 86,175 acres of land on the basis of 2 acre-feet of water per acre for irrigation purposes, an amount amply sufficient in the light of existing data.

It has been shown that there are lying under and could be irrigated from Uinta River 76,785 acres of land. Consequently the entire supply of the river will be disposed of, except for a small surplus on the side of safety.

WHITE ROCKS RIVER.

The mean monthly discharge of White Rocks River from 1899 to 1902 was as follows:

Estimated mean monthly discharge of White Rocks River at Canyon station.

[Drainage area, 114 square miles.]

Month.	Discharge in second-feet.	Total in acre-feet.	Run-off.	
			Second-feet per square mile.	Depth in inches.
1899.				
September	86	5,117	0.76	0.84
October	80	4,919	.70	.81
November	66	3,927	.58	.64
December	63	3,874	.55	.63
1900.				
January	47	2,890	.41	.47
February	48	2,666	.42	.44
March	50	3,074	.44	.51
April	44	2,618	.39	.44
May	400	24,595	3.51	4.00
June	253	15,055	2.22	2.48
July	82	5,042	.72	.83
August	62	3,812	.54	.62
September	55	3,273	.48	.54
October	44	2,705	.39	.45
November	59	3,514	.52	.58
December	55	3,382	.48	.55
The year	100	72,623	.88	11.96
1901.				
January	50	3,074	.44	.51
February	50	2,777	.44	.46
March	50	3,074	.44	.51
April	74	4,403	.65	.73
May	507	31,174	4.45	5.13
June	179	10,651	1.57	1.75
July	101	6,210	.89	1.03
August	128	7,870	1.12	1.29
September	95	5,653	.83	.93
October	75	4,612	.66	.76
November	63	3,749	.55	.61
December	61	3,751	.54	.62
The year	119	86,998	1.05	14.33

Estimated mean monthly discharge of White Rocks River at Canyon station—Continued.

Month.	Discharge in second-feet.	Total in acre-feet.	Run-off.	
			Second-feet per square mile.	Depth in inches.
1902.				
January	48	2,924	0.42	0.48
February	41	2,297	.36	.37
March	48	2,955	.42	.48
April	57	3,416	.50	.56
May	471	28,947	4.13	4.77
June	348	20,704	3.05	3.40
July	109	6,684	.96	1.11
August	67	4,094	.59	.68
September	57	3,410	.50	.56
October	53	3,255	.46	.53
November	48	2,830	.42	.47
December	44	2,705	.39	.45
The year	116	84,221	1.02	13.86

The discharge in 1903 was 101,000 acre-feet.

The preceding tables show an average yearly discharge of 86,210 acre-feet, which would probably be the average for a period of years.

The land that could be most advantageously irrigated from this stream is given on page 567, as follows:

Lands irrigable from White Rocks River.

	Acres.
Under White Rocks River, on reservation	34,240
Strip, off reservation	7,000
Green River area, off reservation	21,200
Total	62,440

This area is more than sufficient to use the entire supply of White Rocks River. On the assumption that 2 acre-feet are necessary, there would be only water sufficient for 43,105 acres, with no allowance for evaporation and seepage.

LAKE CREEK.

The following tables show the estimated **mean monthly discharge** of Lake Creek:

Estimated mean monthly discharge of Lake Creek at mouth.

[Drainage area, 470 square miles.]

Month.	Discharge in second-feet.	Total in acre-feet.	Run-off.	
			Second-feet per square mile.	Depth in inches.
1901.				
January		[a] 8,300		
February		[a] 7,550		
March		[a] 9,690		
April		[b] 11,115		
May		[b] 57,230		
June		[b] 40,510		
July	195	11,990	0.41	0.47
August	97	5,964	.20	.23
September	112	6,664	.24	.27
October	117	7,194	.25	.29
November	115	6,843	.24	.27
December	124	7,624	.26	.30
The year		180,734		
1902.				
January	95	5,841	.20	.23
February	95	5,276	.20	.21
March	100	6,149	.21	.24
April	132	7,855	.28	.31
May	1,272	78,212	2.68	3.09
June	556	33,084	1.17	1.31
July	250	15,372	.53	.61
August	255	15,679	.54	.62
September	144	8,569	.30	.33
October	132	8,116	.28	.32
November	112	6,664	.24	.27
December	110	6,764	.23	.27
The year	271	197,581	.57	7.81

[a] [illegible] approximate.

[b] [illegible] River at Price Road Bridge.

Estimated mean monthly discharge of Lake Creek at mouth—Continued.

Month.	Discharge in second feet.	Total in acre-feet.	Run-off.	
			Second-feet per square mile.	Depth in inches.
1902.				
January	90	5,534	0.19	0.22
February	90	4,998	.19	.20
March	97	5,937	.20	.23
April	109	6,512	.23	.26
May	718	44,168	1.51	1.74
June	1,238	73,700	2.61	2.91
July	220	13,500	.46	.53
August	108	6,650	.23	.27
September	88	5,232	.18	.20
October	97	5,994	.20	.23
November	109	6,512	.23	.26
December	90	5,534	.19	.22
The year	264	184,271	.54	7.27

The estimated discharge for 1903 is 190,000 acre-feet.

The preceding tables show an average discharge of 187,500 acre-feet.

The table on page 565 shows that the territory lying under Lake Creek, which can be most economically irrigated from that stream, consists of 57,520 acres. On that basis there is water sufficient for more than 35,000 acres of land more than can be found in the immediate vicinity. This, however, could be disposed of to excellent advantage on the bottom lands lying along Duchesne River, lessening the demand on that stream by 33,300 acres and leaving it free for the work of supplying the land to the east represented by the Bench and Sixmile Draw. These last are estimated to comprise 33,000 acres, an area which, in all probability, might be increased.

DUCHESNE RIVER.

The discharge of Duchesne River from 1899 to 1902 was as follows:

Estimated mean monthly discharge of Duchesne River below junction with Lake Creek.

[Drainage area, 2,746 square miles.]

Month.	Discharge in second-feet.	Total in acre-feet.	Run-off.	
			Second-feet per square mile.	Depth in inches.
1899.				
October	403	24,799	0.15	0.17
November	398	23,683	.14	.16
December	347	21,336	.13	.15
1900.				
January	370	12,750	.13	.15
February	370	20,549	.13	.14
March	394	24,226	.14	.16
April	467	27,788	.17	.19
May	2,327	143,082	.85	.98
June	1,702	101,276	.62	.69
July	377	23,181	.14	.16
August	271	16,663	.10	.12
September	296	17,613	.11	.12
October	313	19,246	.11	.13
November	305	18,149	.11	.12
December	342	21,029	.12	.14
The year	623	455,552	.23	3.07
1901.				
January	280	17,217	.10	.12
February	280	15,550	.10	.10
March	289	17,770	.11	.13
April	498	29,633	.18	.20
May	3,169	194,854	1.15	1.33
June	1,485	88,364	.54	.60
July	597	36,708	.22	.25
August	453	27,854	.16	.18
September	307	18,268	.11	.12
October	322	19,799	.12	.14
November	316	18,803	.12	.13
December	300	18,446	.11	.13
The year	691	503,266	.25	3.43

Estimated mean monthly discharge of Duchesne River below junction with Lake Creek—Con.

Month.	Discharge in second-feet.	Total in acre-feet.	Run-off.	
			Second-feet per square mile.	Depth in inches.
1902.				
January	280	17,217	0.10	0.12
February	280	15,550	.10	.11
March	291	17,875	.11	.13
April	656	39,035	.24	.27
May	1,969	121,069	.72	.83
June	2,239	133,235	.82	.91
July	555	34,138	.20	.23
August	273	16,804	.10	.12
September	258	15,364	.09	.10
October	297	18,288	.11	.13
November	322	19,152	.12	.13
December	300	18,447	.11	.13
The year	644	466,174	.24	3.21

The estimated discharge for 1903 is 490,000 acre-feet.

Estimated monthly discharge, in acre-feet, of Duchesne River above mouth of Lake Creek.

[Drainage area, 2,247 square miles.]

	1900.[a]	1901.[a]	1902.[a]
1902.			
January	14,390	11,376	11,683
February	12,999	10,274	40,552
March	14,536	11,621	11,938
April	16,663	21,778	32,523
May	85,852	116,642	76,901
June	60,866	55,280	59,535
July	11,191	21,336	20,638
August	10,699	12,475	10,154
September	10,949	9,699	10,132
October	12,052	11,683	12,294
November	11,306	12,139	12,640
December	13,405	11,682	12,813
The year	274,908	305,685	281,903

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[a] These amounts were obtained by taking the discharge of Lake Creek at its mouth from that of Duchesne River at Price Road Bridge, 3 miles below. The discharge for January to June, inclusive, is approximate.

The discharge for 1903 is estimated to have been 300,000 acre-feet.

As the discharge of Lake Creek, the most important tributary of Duchesne River, has been disposed of, there remains to be considered only the discharge of Duchesne River above the mouth of Lake Creek. The foregoing tables show an average yearly discharge of 287,500 acre-feet—sufficient to irrigate successfully in that locality 145,000 acres, an area largely in excess of the available land. If the bottom lands along the Duchesne are to be irrigated from Lake Creek, there are, so far as shown by present knowledge, only 33,000 acres to be provided for. It is possible, however, that water could be carried farther along on this high-level plane, so as to cover land on the old Uncompahgre reservation; this, however, is mere conjecture, with no knowledge to back it.

SUMMARY.

Before any broad plans for the reservation are adopted some provision must be made looking to the adjustment of the present and more especially the future water rights, as this question will become a burning one as soon as the land is thrown open to settlement.

Agricultural lands are properly the lands on which water can be had throughout the season when irrigation is necessary. Consequently it is not the months when the rivers are full and in flood, but rather those toward the latter part of the season, say July and August, that act as the controlling factor, as it is absolutely necessary that there shall be no shortage during those months. Unless provision is made to artificially furnish water during this period the only resource at hand is the actual discharge of the streams, which consequently determines the amount of available land to be disposed of.

The following tables show the water supply during July and August for the years 1900, 1901, 1902, and 1903 for Uinta and White Rocks rivers at the Canyon station, and for Lake Creek and Duchesne River:

Mean discharge, in second-feet, of Uinta River in July and August, 1900-1903.

Year.	July.	August.
1900	223	184
1901	251	242
1902	262	181
1903	382	232

Uinta River therefore will on the average supply water enough, with a duty of 1 second-foot to 100 acres, to irrigate 22,475 acres.

Mean discharge, in second-feet, of White Rocks River for July and August, 1900–1903.

Year.	July.	August.
1900	82	62
1901	101	128
1902	109	67
1903	198	93

It is thus possible to cultivate from White Rocks River alone, with the same duty of water 9,175 acres.

Mean discharge, in second-feet, of Lake Creek for July and August, 1900–1903.

Year.	July.	August.
1900	195	97
1901	250	255
1902	220	108
1903	411	157

Lake Creek therefore will supply a mean acreage of 20,150 acres for the period, using the same duty for water of 1 second-foot to 100 acres.

Mean discharge, in second-feet, of Duchesne River above mouth of Lake Creek for July and August, 1900–1903.

Year.	July.	August.
1900	180	172
1901	344	196
1902	330	163
1903	501	218

It is therefore possible to cultivate with the natural flow of Duchesne, above Lake Creek alone, 23,680 acres.

IRRIGABLE LANDS.

The areas that could be irrigated are as follows:

Summary of land irrigable in July and August, 1900–1903.

	Acres.
Uinta River	22, 475
White Rocks River	9, 175
Lake Creek	20, 150
Duchesne River	23, 680
Total	75, 480

It has been shown that the amount of land necessary to properly provide for these Indians, assuming that the unallotted Uncompahgres will be situated on this reservation, will be as follows:

Lands necessary to provide for Indians.

	Acres.
Uinta and White River Utes	49,880
Uncompahgre Utes	9,760
Total	59,640

As it does more harm than good to flood lands extensively, without storage the enormous amount that goes to waste during the flood period of the year will have to be almost cut out as far as any benefit to the lands is considered. Therefore it appears that the amount of land free for settlement by outside parties is reduced to a minimum and that in view of the future needs of the lands which may be allotted to the Indians there is not much water which can be otherwise appropriated without injury to them.

In this discussion the assumption has been kept in view that the Indians are to remain on their lands and cultivate them for a livelihood, but that probably is expecting too much. If the law is interpreted to mean that these "prospective wants" shall govern the amount of land to be disposed of, conditions as they exist at present will scarcely be altered. The intent of the law in opening this land for settlement from the outside will be practically defeated and the greater portion of the reservation will remain as it has been, a barren waste.

In view of this situation, the only apparent solution of the problem, and the most natural one that presents itself, is to devise some means whereby the enormous waste during the flood season will be conserved, and in that way a garden spot brought into existence on land which at present will hardly support the wild ponies that roam it at will.

Beyond doubt railroad connections will soon be made with this part of Utah, and, as this is known as a very productive country, it is safe to say that settlers will promptly move in and take up land if a water supply is assured.

RESERVOIR SITES.

UINTA CANYON.

A reconnaissance of Uinta Canyon was made September 13, 14, and 15, 1903, with a view of determining if there were any possible sites for reservoirs. Only one worthy of any consideration was found, but fortunately this is located almost at the canyon's end.

This examination was verified and more positive evidence and information taken on October 14, 1903, though no measurements were made except with the eye, and such, of course, are only approximate.

The location of this reservoir is about 4 miles above the gaging station on the river, at the only place where water of any consequence can be impounded in the entire canyon. Above it the river flows in a series of gorges and sharply defined canyons.

After leaving the upper canyon Uinta River flows through a rather small well-defined basin, bordered on three sides by very precipitous cliffs over 100 feet in height. Below this basin a gorge has been cut, varying in width from about 400 to 1,000 feet. The walls extend to the first shelf, or bench, at an elevation of possibly 175 to 200 feet. This bench reaches to the foothills of the range, and offers an opportunity for building a dam whose height will be limited only by the bounds of safe construction.

Approximately the valley is about 4½ miles long by about one-half mile wide, surface area, which, although comparatively small, would, in conjunction with another reservoir on White Rocks River, impound sufficient water to be of quite material assistance during the months of low water should conditions ever present themselves (as they will when the reservation is opened) when a shortage of water will occur and artificial means must be resorted to to increase the area of cultivated land.

There is no outcrop of rock in the vicinity, and it is difficult to determine the character of the underlying strata, so that the question of the dam is of major importance. In view of these conditions it is hardly safe to even attempt to submit figures of the possible quantities or costs.

WHITE ROCKS CANYON.

In White Rocks, as in Uinta Canyon, the only site that would permit the storage of practically any water is almost at the very mouth of the canyon, where nature has provided a most admirable location both for a dam and a reservoir. Its capacity is only limited by the height of the dam, and this in turn, on account of the amount of good stone at hand, is only limited by the practical bounds of safe construction.

At this point there is a gorge about 150 feet wide at its base, with a left wall 20 feet high, rising almost from the water's edge, and a right wall of rock extending upward almost perpendicularly for 1,000 feet or more.

It is almost certain that there is a good foundation for a dam and that plenty of good firm sandstone is at hand for the construction of whatever sized dam may be necessary to impound whatever water can be retained at this place.

It is extremely difficult to give even approximate quantities and costs on this scheme, for the capacity can be only determined by a survey, and the nature of the foundation and underlying strata is solely a matter of conjecture at present.

The discharges of White Rocks River for the years observations have been maintained are as follows:

Discharge of White Rocks River.

	Acre-feet.
1900	72,623
1901	86,998
1902	84,221

Fifty per cent of this discharge comes during the months of May and June, and the greater portion goes to waste. In July and August, the two months when water is most needed, the river flow is normal. Without storage it is difficult to see how it will be possible for outside parties to increase the cultivated area when the Indians have been allotted these lands and have preempted the now available water.

This condition prevails or will prevail on the Uinta and White Rocks areas, where the best land lies, and where in all probability the greater part of the Indians will be located.

DUCHESNE RIVER AND LAKE CREEK.

On Duchesne River and Lake Creek no examinations have been made as to the possibility of storing water, but reservoir sites are said to exist at the headwaters. The source of Lake Creek is a lake, or series of lakes, lying under the Uinta Mountains, which may be made capable of retaining a large portion of the water which now goes to waste.

ASHLEY CREEK.[a]

INTRODUCTION.

In no portion of Utah are there better opportunities for agriculture than in the northeastern section, where the Green River flows uninterrupted for many miles through virgin soil, the productiveness of which is well demonstrated on lands bordering the banks of its many affluents.

The largest cultivated area and the best example of intensive farming to be found in Uinta County, which has an area of over 3,300,000 acres, is in what is known as Ashley Valley, a beautiful valley nestling under the foothills of the Uinta Mountains and receiving its waters from Ashley Creek.

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[a] From report by Howard S. Reed.

LOCATION AND PHYSICAL CHARACTERISTICS.

The many branches of Ashley Creek, draining approximately 250 square miles in northeastern Utah, are situated entirely within the Uinta Forest Reserve, in Uinta County, between the drainage areas of Brush Creek, Green River, and the Uinta River.

These branches receive their waters from a series of small lakes on the summit and the southern slopes of the Uinta Mountains, thus insuring a never-ending supply.

The branches finally join at the base of the mountains, and the creek enters Ashley Valley in one stream 8 miles above the town of Vernal, the corporate limits of which are within sec. 23, T. 4 S., R. 21 E. of the Salt Lake meridian.

Ashley Valley is approximately 22 miles in length by from 3 to 4 in width, and contains about 49,280 acres of arable land, whose boundaries are very prominently defined and established by the foothills at the base of the range.

The creek meanders through the valley in a southeasterly direction and finally enters Green River at the foot of the valley, about 20 miles below the point where the latter stream crosses the State line between Utah and Colorado.

A peculiar feature of the streams between the Uinta River drainage area and Green River is that at some point in their course they disappear except during the spring floods, and that all, with the exception of Dry Fork, which is the most westerly branch of Ashley Creek, reappear again miles farther along every year. Only three times since 1879 has water reappeared in the channel of Dry Fork after the spring floods have subsided; this has occurred in the present year. Dry Fork disappears seemingly altogether in one sink, where it forms a pool, about 12 miles above the junction of this branch and Ashley Creek proper.

Ashley Creek, Big Brush Creek, and Little Brush Creek carry all their water until they reach a very pervious soil, when the water gradually seeps out of sight. The part of the water of Big Brush and Little Brush creeks that fails to seep away during the period of high water is carried over this porous ground and enters long precipitous tunnels or caves.

As not only the two Brush creeks and Dry Fork, but Ashley Creek itself, below the junction of its north and south forks and above where it enters its gorge, is of this nature, a reconnaissance of Dry Fork was made in August, 1901, when the following data were obtained:

Dry Fork has its source in a lake in the Uinta Mountains about 35 miles northwest of Vernal.

It has a length of about 28 miles; for 23 miles it flows in a canyon varying from 500 feet to one-half mile in width. Its general direction is southeast and its fall is heavy—at least 150 feet per mile. It enters Ashley Creek about 8 miles above the town of Vernal. About midway of the stream's length, or 10 miles northwest of Dry Fork post-office, a gaging was made on August 20, 1901, which gave a discharge of 96 second-feet. About 1,200 feet below this point occurs a pool, or sink, lying in a circular basin, whose banks, except on the upstream side, are from 75 to 100 feet high. The stream enters this pool through several inlets.

The pool is apparently bottomless; the water in its larger end has a slow circular motion, but whether this is caused by the incoming stream or by suction from below could not be determined.

The only visible outlet is a narrow, rocky channel which has been widened by blasting in an effort to increase its flow. When visited this carried about 10 second-feet, all of which sank within a mile or thereabouts.

Three miles below the pool the north branch comes in. One mile above its mouth the flow was 8 second-feet, but the water vanished almost immediately upon reaching the main channel. Seven miles below the pool are located several springs, the upper and largest one being a hole 25 feet in diameter. This pool was perfectly dry, but at the lower ones there was an outflow of 33 second-feet.

A resident in Dry Fork settlement since 1879 stated that only once before, to his knowledge, had these springs furnished water after the subsidence of the usual spring freshet. It was also stated that owing to recent rains the stream above the pool was higher than usual.

Two miles below the springs, at the canyon mouth, two ditches are located, but they had carried no water for several weeks.

The stream bed was dry from the heads of the ditches to its mouth, 5 miles farther.

About 250 feet above the mouth of Dry Fork a gaging of Ashley Creek showed 132 second-feet. At another point 400 feet below the mouth the discharge was 128 second-feet. A closer check than this would probably be impossible in view of the rather rough character of the creek's bed. One mile below Dry Fork, at the regular gaging station, the discharge was 154 second-feet.

The increase shown here is partly due to a ditch diverting water from the east side of Ashley Creek, a short distance above the mouth of Dry Fork, and returning the water to the creek again above the gaging station.

It seems hardly possible that the increase is due entirely to this ditch. Probably all this water sooner or later finds its way to its natural basin, Green River, and all the many strange appearances of water, notably that on Deep Creek, on the other side of the intervening hills, are from the general underground flow, which receives so many liberal contributions in this vicinity.

Two small ditches, carrying a total of 3 second-feet, are taken out of Ashley Creek between Dry Fork and the gaging station.

TOPOGRAPHY.

The country tributary to Ashley Creek is very rugged and mountainous.

The peaks in the range to the north attain elevations of from 12,000 to 12,255 feet above sea level, and the greater portion of its drainage area is above the 7,000-foot contour.

Between the 7,000- and the 9,000-foot contours are exceedingly large and level flats miles in extent, which afford excellent grazing for numerous herds of cattle and sheep.

In the upper reaches are magnificent belts of pine and cottonwood trees, which, being within the Uinta Forest Reserve, are assured of good protection, thereby protecting the water supply.

In many places the mountains themselves form the immediate banks of the creek, rising in almost perpendicular cliffs several hundred feet high.

In consequence of the proximity of the outcropping rock, the stream bed is very rocky throughout its entire length, owing to the bowlders being carried downstream during periods of high water.

The valley suddenly flattens out at the point where the stream enters, and throughout its extent is covered with highly productive soil.

PRECIPITATION.

The Weather Bureau has maintained an observer at Vernal for nine years, and has kept a continuous record for this period. The record presented here is simply for the valley, no data being available of the precipitation in the mountains. No records have ever been obtained either here or in any other section of the range, except at Heber on the other face of the mountains, which perhaps might throw some light on the question of rainfall. The Heber records, however, are very incomplete, making it impossible to give an accurate average. Probably the precipitation will reach very nearly 15 inches per year.

Records since 1889 are available at Fort Duchesne, 28 miles west of Vernal, and these serve to verify the assumption that an increase in altitude will produce a corresponding increase in precipitation. Fort Duchesne is 5,016 feet above sea level; Vernal 5,356 feet, and Heber, 5,606 feet. Consequently there is no doubt but what the mountains, the peaks of which attain elevations of over 12,000 feet, receive much more rainfall and snowfall.

The variation in precipitation at Vernal, as will be seen by the table, is somewhat pronounced when the total rainfall for the year is taken into consideration, and the peculiar fact is presented that the three lowest years were consecutive—1900, 1901, and 1902. Other than this period of three years the precipitation is rather uniform, with only one year, 1897, showing an excess over 1903, the year in which the heaviest discharge is registered.

Should this rainfall and snowfall record be a true index of the stream discharge, it would appear that Ashley Creek is capable of discharging a much larger amount of water than was discharged in 1903. But notwithstanding an increase in precipitation in 1902 over 1901, the discharge in 1901 was almost 20 per cent more than in 1902. So that perhaps this may be rather an unstable factor in this locality, and the precipitation in the valley may not be wholly indicative of what may be expected to happen regularly in the mountains.

The mean for Vernal in the nine years is 8.46 inches.

This precipitation could have very little perceptible effect on the flow of the stream after it reaches the valley, for where these observations are kept the run-off is at a minimum. It is seldom that any great amount of rain or snow falls at any one time, and what does fall would practically be all consumed in the immediate vicinity on the agricultural lands and could only be taken into consideration in connection with the amount necessary to be drawn from any source where water was conserved to make up the amount of moisture necessary to successfully irrigate lands in this locality.

As will be seen by the table, the precipitation is well distributed throughout the year, there being no particularly well-defined wet or dry season. Fortunately, however, in this community, as in some others in the West where water is the most important commodity, a good proportion of what rainfall there is comes during May, June, July, August, and September, the months when it is most needed.

The following tables give the precipitation at Fort Duchesne, Vernal, and Heber:

Precipitation, in inches, at Fort Duchesne, Utah.

[Elevation, 5,016 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1889	0.35	0.18	0.32	0.68	0.73	0.15	0.49	0.56	0.34	0.66	0.05	1.77	5.28
1890	1.01	.27	.02	.21	.00	.00	1.35	.85	.32	1.17	.03	.27	5.50
1891	.22	.28	.57	.99	.96	.34	.24	1.42	1.46	.00	.00	1.06	7.54
1892	.40	.30	.78	1.24	1.35	.03	.16	.08	Tr.	.46	.14	.46	5.40
1893	.42	.44	3.10	2.01	.92	.00	.47	.57	.36	.16	.24	.49	9.18
1894	.08	.19	.56	Tr.	.20	.34	.26	.30	1.88	.34	.00	.69	4.84
1895	.09	.03	.09	.00	1.53	1.02	.17	.20	.08	.13	.90	.31	4.50
1896	.60	.09	.14	.21	1.40	.03	1.45	.64	2.23	.54	.20	.00	6.89
1897	.87	.90	.28	.01	.16	.02	.17	.21	4.61	3.00	.00	1.20	11.43
1898	.60	.10	.75	.17	.61	.45	.66	.66	.08	.05	.13	.10	4.36
1899	.20	.40	2.10	.60	.00	.05	.71	.90	.00	.83	.00	1.20	6.59
1900	.35	.00	.00	1.72	.15	.06	.08	.40	1.25	.27	.51	.30	5.09
1901	.25	.95	.15	.20	.60	.08	.14	2.47	.03	.64	.16	.51	6.18
1902	1.70	.05	.14	.70	.30	.50	.05	.00	1.45	.00	.00	.00	4.89
1903	.00	.80	.08	.00	1.02	.28	1.49	.20	1.20	.48	.00	.00	5.55

Mean for period 1889 to 1903, inclusive, fifteen years, 6.22.

Precipitation, in inches, at Vernal, Utah.

[Elevation, 5,356 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1895	1.00	0.54	1.30	0.08	1.51	0.53	0.76	0.40	0.38	1.03	1.33	0.27	9.13
1896	.48	.29	.38	.89	.94	.04	1.86	0.58	2.48	.69	.42	.04	9.09
1897	.96	1.11	.86	.58	.62	.23	1.08	.26	2.83	2.34	.42	1.20	12.69
1898	.63	.47	.60	.50	2.03	.45	.34	.66	1.04	.30	.39	.17	7.50
1899	.40	.55	1.93	.39	(a)	.78	(a)	1.63	(a)	(a)	(a)	(a)	8.46
1900	.47	.12	.15	2.00	.26	.14	.03	.22	1.46	.57	1.21	.04	6.67
1901	.71	1.36	.31	.33	.86	.21	.21	.73	.04	.42	.27	.48	5.93
1902	.21	.51	.86	.72	.42	.51	.12	.46	.99	.05	1.12	.97	6.94
1903	.39	.96	1.02	.67	1.30	.89	1.83	.13	1.50	.88	.18	.00	9.75
Mean	......	......	......	......	......	......	......	......	......	......	......	......	8.46

a Fort Duchesne record.

Precipitation, in inches, at Heber, Utah.

[Elevation 5,606.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1893	1.00	2.95	3.35	2.15	0.76	0.02	0.27	0.68	0.28	0.73	1.60	3.95	17.84
1894	3.65	1.60	1.65	.41	.54	.79	.62	1.16	2.47	1.70	.00	2.60	17.19
1895 a	3.22	1.93	1.45	.48	1.54	.25	1.37	Tr.	.50	.40	.60	......	....
1896 a	2.10	.95	2.46	2.40	1.85	.09	3.35	.55	1.44	......	......	.75	....
1897 a	1.30	4.10	2.90	.90	.70	.38	.56	.49	3.14	1.50	1.00	......	....
1898 a	1.40	.50	3.30	1.25	......	.83	.25	.64	......	1.44	1.60	1.10	....
1899 a	2.45	5.85	3.00	.89	......	.97	......	2.10	.15	......	......	......	....
1900	1.06	1.50	.34	2.53	.16	.20	.25	.31	1.20	1.47	4.42	.22	13.60
1901	2.20	2.20	1.56	.31	1.72	.08	.40	2.06	.16	1.70	1.40	1.50	15.29
1902	.50	1.03	1.46	1.88	.49	.37	.15	.50	.45	.45	1.77	1.04	10.09
1903	2.17	.70	1.95	.78	1.42	.25	.69	.20	1.17	.76	1.90	1.33	13.32

a Record incomplete.

WATER SUPPLY.

A gaging station was established on Ashley Creek, under the direction of C. C. Babb, in the early part of 1900, and daily observations of the river's height have been made from that time until the present.

Occasional measurements have been made by different hydrographers during this period, from which discharge curves and rating tables have been constructed, thereby establishing the available water supply.

Between the years 1900 and 1903 there is considerable difference, but it is thought that they are representative years as to the maximum and minimum discharges, while the flow in 1901 and 1902 represents the average.

Throughout the early months of the year, January, February, March, and April, the flow is very uniform, and is usually at its lowest point. After the first of May the flow gradually increases, owing to melting snows in the mountains, and late in May or early in June the river is at its maximum height. This usually lasts but a few days, and the discharge gradually decreases until the normal summer flow, which will usually continue throughout the balance of the year, is reached. During the low period the river is maintained by the melting of the snow banks near the crest, which in some years never entirely disappear.

Notwithstanding the fact that the duration of the high water is limited to a very short period of time, more than one-half of the entire discharge for the year is carried during that period.

The following table shows the per cent of the total discharge carried during May and June for each year since observations have been maintained:

Percentage of total discharge of Ashley Creek carried in May and June.

	Per cent.
1900	63
1901	55
1902	60
1903	68

This table alone demonstrates the necessity of an artificial supply should it be desired to increase the cultivated area lying within reach of the water of this stream, the present area being strictly limited by the water available during the late summer and early fall months, when perhaps water is most needed to bring the crops to maturity.

The following table shows the discharge measurements made since work was commenced in this locality:

Discharge measurements of Ashley Creek, at Station No. 8, 7½ miles northwest of Vernal Utah.

No.	Date.	Hydrographer.	Meter number.	Gage height.	Area of section.	Mean velocity.	Discharge.	Remarks.
	1900.			*Feet.*	*Sq. ft.*	*Ft. per sec.*	*Sec.-ft.*	
1	Feb. 8	C. T. Prall	63	....	20	1.70	34	Wagon bridge.
2	Mar. 15	.....do.........	63	0.48	21	1.78	37	Do.
3	May 1	.....do.........	63	.62	39	1.16	45	Do.
4	May 28	C. C. Babb	63	3.20	153	5.08	776	Do.
5	June 11	C. T. Prall	63	1.74	83	3.71	306	Do.
6	July 23	O. R. Stewart..	87	.67	41	1.76	72	Wading 200 feet above bridge.
7	....do...	.....do.........	87	.67	28	2.93	83	Wading at bridge.
8	Aug. 21	C. C. Babb	353	.60	33	1.21	40	Wading 200 feet above bridge.
9	Nov. 12	C. T. Prall	63	.55	34	1.40	47	Wading.
	1901.							
10	May 30	L. V. Branch...	127	2.78	101	4.77	484	From bridge.
11	June 21	.....do.........	127	1.23	39	4.00	155	Do.
12	Aug. 21	C. T. Prall	127	....	42	3.12	132	250 feet above mouth of Dry Fork.
	....do...	.....do.........	127	....	49	2.59	128	400 feet below.
	....do...	.....do.........	127	1.15	57	2.70	154	By wading 100 feet above bridge.
13	Oct. 30	.....do.........	127	.78	42	1.77	74	Do.
	1902.							
14	Mar. 14	C. T. Prall	127	.60	32	1.42	46	Do.
15	July 16	Reed and Prall	88	1.00	44	2.34	104	Do.
16	Nov. 6	H. S. Reed	88	.60	33	1.30	43	Do.
17	Dec. 12	.....do.........	88	.60	34	1.18	40	Do.
	1903.							
18	Jan. 31	H. S. Reed	88	1.00	36	1.08	39	Gage height inacurate—ice.
19	Apr. 12	.....do.........	116	.60	31	1.30	41	Wading at register station
20	May 12	.....do.........	116	2.70	93	5.28	500	
21	June 8	.....do.........	116	4.23	316	5.33	1,685	
22	Aug. 24	.....do.........	116	1.80	41	2.12	87	
23	Sept. 23	.....do.........	116	1.75	41	1.80	74	
24	Nov. 9	.....do.........	116	1.60	34	1.53	52	

The total discharge of the creek has been computed month by month for the entire period since measurements were commenced, embracing the years 1900, 1901, 1902, and 1903.

The results of these computations are shown in the following tables, which show the maximum, minimum, and mean during each month; the total discharge in acre-feet, with the run-off in second-feet per square mile of drainage area, and the depth in inches for each month.

These tables represent the total surface flow of Ashley Creek, including the overflow from Dry Fork, which discharges into the main channel during the season of high water. After the subsidence of the spring floods the main stream receives nothing from Dry Fork—

nothing, at least on the surface. The discharge is simply that which comes down the main stream of Ashley Creek.

Estimated monthly discharge of Ashley Creek near Vernal, Utah.

[Drainage area, 250 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Rainfall.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Inches.
1900.							
January	....	....	35	2,152	0.14	0.16	0.47
February	....	....	35	1,944	.14	.15	.12
March	37	37	37	2,275	.15	.17	.15
April	49	37	40	2,380	.16	.18	2.00
May	859	43	478	29,391	1.91	2.20	.26
June	534	112	245	14,578	.98	1.09	.14
July	102	55	74	4,550	.30	.35	.03
August	49	40	45	2,767	.18	.21	.22
September	64	37	43	2,559	.17	.19	1.46
October	55	43	44	2,705	.18	.21	.57
November	49	40	42	2,499	.17	.19	1.21
December	40	37	38	2,337	.15	.17	.04
The year	859	37	96	70,137	.39	5.27	6.67
1901.							
January	36	36	36	2,214	.14	.16	.71
February	43	36	36	1,999	.14	.15	1.36
March	55	34	37	2,275	.15	.17	.31
April	864	34	122	7,260	.49	.55	.33
May	1,136	354	683	41,996	2.73	3.15	.86
June	444	141	232	13,805	.93	1.04	.21
July	141	72	100	6,149	.40	.46	.21
August	932	72	149	9,162	.60	.69	.73
September	131	72	96	5,712	.38	.42	.04
October	72	55	62	3,812	.25	.29	.42
November	63	48	58	3,451	.23	.26	.27
December	55	48	52	3,197	.21	.24	.48
The year	1,136	34	139	101,032	.55	7.58	5.93
1902.							
January	50	45	45	2,777	.18	.21	.21
February	45	45	45	2,498	.18	.19	.51
March	45	40	42	2,608	.17	.20	.86

Estimated monthly discharge of Ashley Creek near Vernal, Utah—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Rainfall.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Inches.
1902.							
April	315	40	78.0	4,665	0.31	0.35	0.72
May	882	315	533.0	32,765	2.13	2.46	.42
June	636	152	306.0	18,226	1.22	1.36	.51
July	164	62	108.0	6,627	.43	.50	.12
August	62	55	56.0	3,429	.22	.25	.46
September	69	45	52.0	3,096	.21	.23	.99
October	55	50	52.0	3,103	.21	.24	.05
November	55	45	46.0	2,737	.18	.20	1.12
December	45	45	45.0	2,767	.18	.21	.97
The year	882	40	117.0	85,298	.47	6.40	6.94
1903.							
January	45	45	45.0	2,767	.18	.21	.39
February	45	45	45.0	2,499	.18	.19	.96
March	69	37	42.0	2,582	.17	.20	1.02
April	315	45	94.0	5,593	.38	.42	.67
May	1,267	286	602.0	37,016	2.41	2.78	1.30
June	2,065	236	893.0	53,140	3.57	3.98	.89
July	270	105	172	10,580	.688	.793	1.83
August	105	58	76.4	4,698	.306	.353	.13
September	105	47	60.2	3,582	.241	.269	1.50
October	96	47	63.2	3,886	.253	.292	.88
November	58	38	45.3	2,696	.181	.202	.18
December	31	31	31.0	1,906	.124	.143	....
The year	2,065	31	181.0	130,945	.724	9.83	9.75

EVAPORATION AND SEEPAGE.

Unfortunately, as is the case in many other localities in the west, no data are at hand relative to evaporation on Ashley Creek nor on any other stream in the vicinity. Consequently any attempt to determine this most important factor would perhaps not even approach an approximation of the truth.

Seepage, however, takes place to a considerable extent and during the period of low water in the summer, when the entire flow of the stream is distributed through the different canals, the seepage water that finds its way into the stream bed farther down the valley is again distributed pro rata among those entitled to any portion of it. This distribution is made by the water commissioner, but in the division of this seepage water, as in that of the natural flow of the stream, the volume of the flow is never taken into account; the entire amount in the bed of the stream proper, be it much or little, is simply divided into certain shares among those entitled to it, and no attention is paid to the number of second-feet or miner's inches. Consequently this amount also will have to be left as a quantity to be determined in the future.

SILT.

Practically no consideration whatever need be given to the subject of silt or sedimentation in any reservoir constructed in Ashley Canyon, for at all stages the water is as clear as crystal, carrying no foreign matter whatever. This is most fortunate, for any reservoirs constructed there must of necessity be small; fortunately, however, the need is equal to the capacity.

IRRIGATION PERIOD.

The irrigation period in Ashley Valley extends from April 1 to October 1, six months. Under present conditions the area that can be cultivated is determined entirely by the natural flow of the stream during the late summer and early fall months, when a shortage of water would work great damage. This compels the planting of no more land than experience has shown is sure of a water supply during this period.

The stream assumes its normal flow early in July, and, except for the year just past, May has been the only month when the stream has carried more than the combined capacity of the present canals of the valley, which is approximately 350 second-feet. This year, May and June, especially June, the discharge was greatly in excess of that amount.

The following table shows the amount carried by the stream for the past four years during the irrigation period, expressed in acre-feet, and the monthly mean, expressed in second-feet:

Discharge, in acre-feet, of Ashley Creek during irrigation season.

Year.	Apr.		May.		June.		July.		Aug.		Sept.	
	Acre-feet.	*Sec.-feet.*	*Acre-feet.*	*Sec.-feet.*	*Acre-feet.*	*Sec.-feet.*	*Acre-feet.*	*Sec.-feet.*	*Acre-feet.*	*Sec.-feet.*	*Acre-feet.*	*Sec.-feet.*
1900	2,380	40	29,391	478	14,578	245	4,550	74	2,767	45	2,559	43
1901	7,260	122	41,996	683	13,805	232	6,149	100	9,162	149	5,712	96
1902	4,665	78	32,765	533	18,226	306	6,627	108	3,429	56	3,096	52
1903	5,593	94	37,016	602	53,140	893	10,580	172	4,698	76	3,582	60

DUTY OF WATER.

Under the prevailing system of applying the available water to the lands very little accurate data as to the duty of water are at hand. It has been the custom to use all the water that could possibly be gotten, and as no attention is paid to the distribution in the flood season, more water than is necessary is applied to the lands every year, doing more harm than good. The fact that damage is done is borne out by the fact that 1902, with a comparatively small discharge, presents in the case of every staple but one larger averages of production than 1901, with a greater discharge.

Consideration, however, must be given to the fact that in 1902 the river maintained a higher discharge for a longer period than in 1901, thereby contributing a larger volume of water for a greater length of time than in 1901, when the greater portion of the flood water was confined to the month of May, thereby shortening the irrigation period, when all the water desired was at hand.

The following table shows what may be accepted as the duty of water in Ashley Valley.

Owing to different conditions that may have prevailed during this period there may be some error in these computations. For instance, the capacity of the canals is taken as 350 second-feet, their approximate capacity in 1900, no measurements having been made since then when the river has been in flood.

The "acreage under cultivation" was furnished by the State board of statistics and can be accepted as correct for the years 1901 and 1902. That for 1900 is from C. C. Babb's report and 1903 is an approximation simply.

Duty of water and crops in Ashley Valley, Utah.

Year.	Amount of water carried by river during irrigation period.	Month of surplus water.	Combined capacity of canals.	Daily average flows of this surplus over capacity of canals.	Amount of surplus.	Area of cultivated land.	Amount used upon cultivated lands.	Depth of water used per acre.	Mean flow for irrigation period.	Amount of land watered per second-foot.
	Acre-feet.		*Sec.-feet.*	*Sec.-feet.*	*Acre-feet.*	*Acres.*	*Acre-feet.*	*Feet.*	*Sec.-feet.*	*Acres.*
1900	56,225	May	350	128	7,870	17,471	48,355	2.8	133	131
1901	84,084	..do	350	333	20,475	13,072	63,609	4.9	175	75
1902	68,806	..do	350	183	11,252	12,257	57,554	4.7	159	77
1903	114,609	May June	350 350	251 543	47,806	13,000	73,524	5.7	203	64

The following table, showing the average yield per acre of the staple products of Ashley Valley, has been compiled from statistics furnished by the State bureau of statistics.

The data in it confirm the assertion often made by those familiar with the State in general that this locality is particularly fertile. This is borne out by the averages of production per acre, which are in every case larger than the general average for the entire State, except for cultivated hay, the yield of which, in 1901, was considerably less than the State average.

It is to be regretted that data for 1903 relative to this important subject are as yet not available, as that year, like 1902, was fortunate in having its season of high water extend over a considerable length of time, and thus would either confirm or disprove the conclusions that can be deduced from these computations relative to the proper amount of water to be applied to any given area.

Approximate acreage per second-foot.

	Acres.
1900	131
1901	75
1902	77
1903	64

Acreage, total production, and average yield per acre of Uinta County, Utah, and entire State, 1900 to 1902. [a]

Year.	Wheat.			Corn.			Oats.		
	Acreage.	Product in bushels.	Average yield per acre in bushels.	Acreage.	Product in bushels.	Average yield per acre in bushels.	Acreage.	Product in bushels.	Average yield per acre in bushels.
1900 [b]	......	....	20.9	......	....	20.0	......	....	35.9
1901 (Uinta County) [c]	2,047	45,562	22.2	366	10,104	27.6	1,718	58,155	33.8
State average	......	....	17.05	......	....	19.0	......	....	32.9
1902 (Uinta County)	1,636	45,746	28.0	434	12,388	28.5	1,597	65,709	41.1
State average	......	....	18.04	......	....	21.4	......	....	34.3

Year.	Barley.			Rye.			Potatoes.		
	Acreage.	Product in bushels.	Average yield per acre in bushels.	Acreage.	Product in bushels.	Average yield per acre in bushels.	Acreage.	Product in bushels.	Average yield per acre in bushels.
1900 [b]	......	....	36.5	......	....	17.5	......	....	118.0
1901 (Uinta County) [c]	77.0	2,908	37.8	57.0	794.0	13.9	191	32,539	170.3
State average	......	....	30.6	......	....	13.3	......	....	134.3
1902 (Uinta County)	98.0	3,524	36.0	36.0	112.0	31.1	164	33,834	206.3
State average	......	....	32.2	......	....	12.5	......	....	126.7

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[a] Figures for 1903 not available.

[b] Figures by counties are not available, so the average presented is not for this section, but for the entire State.

[c] As far as cultivated area is concerned, Vernal Valley is practically Uinta County.

Acreage, total production, and average yield per acre of Uinta County, Utah, and entire State, 1900 to 1902—Continued.

Year.	Alfalfa hay.			Tame hay.			Wild hay.			Miscellaneous.	
	Acreage.	Product in tons.	Average yield per acre in tons.	Acreage.	Product in tons.	Average yield per acre in tons.	Acreage.	Product in tons.	Average yield per acre in tons.	Pasture, acreage.	Cultivated, not otherwise specified, acreage.
1900[a]			2.65								
1901 (Uinta County)[b].	8,048	19,163	2.38	182	205	1.12	774	1,091	1.41	7,049	87
State average			2.26			2.00			1.25		
1902 (Uinta County)	7,733	23,199	3.00	167	376	2.25	1,021	1,496	1.46	5,656	117
State average			2.31			2.11			1.25		

[a] Figures by counties are not available, so the average presented is not for this section, but for the entire State.

[b] As far as cultivated area is concerned, Vernal Valley is practically Uinta County.

In view of these facts, it is believed that when a uniform supply is assured, 1 second-foot will successfully irrigate 100 acres of land.

The supply will probably be increased by the seepage water which, as irrigation increases and enlarged areas are cultivated, will in time assume no little importance as a factor in the irrigation problems of Vernal Valley.

PRESENT CANAL SYSTEM OF ASHLEY VALLEY.

The question as to whether water can be successfully carried to all these lands in Ashley, or Vernal, Valley is entirely eliminated, as the existing canals prove beyond the shadow of a doubt that it is simply a question of having sufficient funds to construct such canals as may be necessary when the flood waters of Ashley Creek are stored.

The present cultivated area is controlled by the four principal canals, which are as follows: Upper Ashley canal, Central Ashley canal, Rock Point canal, and Island ditch. There are various other small ditches.

Upper Ashley canal, which at present covers the high lands of the valley that are irrigated, is located in the extreme west of the valley. It skirts the wall of the opening to the canyon and comes out upon the irrigable lands with a grade simply sufficient to bring the water to the lands below, which have an area of 11,200 acres, of which not over 60 per cent are irrigated.

It is 12 miles in length, and was built in 1882 by the Upper Irrigation Canal Company, whose stock is divided into 1,120 shares, at an issue value of $25 a share. Each share is supposed to carry with it sufficient water to irrigate 10 acres.

The original capitalization of this company was $28,000, but the value of this stock has so appreciated that at present it is worth $50 per share. The maximum capacity of the ditch is about 180 second-feet.

Central Ashley canal, built in 1880, is 8 miles in length and covers 8,400 acres in the very center of the valley, the greater portion of which, including such limited portion as is used for pasturage, is under cultivation. The capital stock of the company operating the canal—the Ashley Central Irrigation Canal Company—was originally divided into 450 shares at a par value of $50 a share, but a reorganization of the company placed the shares at $100, and they are selling at par, so that the capital stock of the company at the present time is $45,000. Each share is supposed to carry with it the right to sufficiently irrigate 20 acres of land. This stock is very hard to get, as is also the stock in the upper Ashley.

This part of the valley is more thickly settled and has a larger percentage of cultivated area than that lying under the upper canal. The maximum capacity of the canal is 140 second-feet.

Rock Point canal, which is 6 miles in length, is situated on the east side of the valley and covers practically 2,000 acres, 75 per cent of which is irrigated. It was built in 1880 and has a maximum capacity of approximately 25 second-feet. The stock of the company is divided into $106\frac{105}{120}$ shares, issued at $10 a share, each share carrying with it the right to sufficient water to irrigate $7\frac{1}{2}$ acres of land. Its value to-day is probably $5,000 and its cost.

Island ditch is a small canal covering about 900 acres between the two branches of the main stream. It is controlled by the parties owning lands bordering it.

The other small canals of the valley in the upper portion are combined and (except the Steinaker ditch) receive their waters through what is known as the Dodds-Davis head-gate.

The Steinaker ditch heads a short distance above the general weir that supplies the other canals (except the Upper Ashley) and crosses the main stream in a flume a short distance above this general weir.

As a result of the constant litigation and friction existing relative to the equalization of the distribution of especially the low water among the several canals, a friendly suit was entered into, and the district court, under date of November 17, 1897, decreed that the waters of Ashley Creek be divided as follows: Upper Ashley to receive eighty eighty-firsts of one-third of the discharge; Ashley Central to receive eighty-six eighty-sevenths of one-third of the discharge; Rock Point, Union, Turner, Dodds, Island, Steinaker, and Colton to receive seventy-five seventy-sevenths of one-third of the discharge, and the Green River intervenors (people living in the lower part of the valley) to receive the remainder.

In accordance with this decree a water commissioner was appointed to carry out the law. He ordered all canal companies to install weirs, so constructed as to bring the water to a quiet state 60 feet above the weir, thereby regulating the flow so that exactly the same height of water is allowed to pass over each weir, the regulating stake (the top of which is level with the crest of the weir) being placed a short distance above.

No head-gates are necessary in the canals, as the amount of water to go to each is constant, only differing as the total discharge of the stream differs, but when water rights are sold or transferred additions and subtractions are made from and to the width of the weirs themselves. While perhaps not conforming to a mathematically correct division of the water, this method is an exceedingly practical one and has been in all respects eminently satisfactory to all concerned, which is, no doubt, the ideal result to be attained.

The majority of the stockholders of all of these canals are the farmers whose lands are irrigated from the individual ditch in which they hold stock. The stock is private property strictly, and can be disposed of at will, and is often sold to people living in the lower part of the valley, who do not receive an amount of water in proportion to their lands.

This condition of affairs in the valley has been the source of no little trouble and discouragement to the residents. Some real attempts have been made, in a way, to obviate this, but the only substantial result of any agitation in this direction has been the formation by the several canal companies of a general organization, known as the Ashley Valley Water Supply and Irrigation Company, to work collectively in the matter of bettering their water supply.

Briefly, the plan advanced by this association has been the consolidation of all the various water interests into one general company, which would have supervision over the distribution of all waters and might augment the present supply. Serious consideration has been given the possibility of storing more of the flood waters for use in the late summer and early fall months by throwing up inexpensive dams at the outlets of the several lakes at the sources of the branches of Ashley Creek.

The size of the lakes demonstrates that only a limited increase could be secured by this means. The following table shows the area, in acres, of each lake, this area corresponding with the increase in the height of the water as determined by the dam that could be constructed.

Capacities of lake reservoirs at heads of Ashley Creek branches.

	Acres.
Delmonico Lake	51.6
Deer Lake	33.8
Gorge Lake	13.8
Mirror Lake	9.9
Lower Deer Lake	16.5
Porphyry Lake	15.5
Timber Line Lake	5.0
Fish Lake	19.7
Total	165.8
Twin Lakes on Dry Fork	60.8
Total	226.6

In this connection the construction of a flume upon Dry Fork to carry its waters over all known sinks, so as to use it in the valley below, has been considered.

As the amount of storage capacity derived from this work would be exceedingly small—for the lakes would only have a depth of from 5 to 12 feet—it is probable that the expense incurred would be hardly warranted.

IRRIGABLE LANDS.

As stated upon page 581, this valley, lying under and receiving its supply of water for practically all purposes from Ashley Creek, contains approximately 49,280 acres of good land, of which 90 per cent, or 45,000 acres, are irrigable and susceptible of cultivation and will produce crops equally as good and heavy as those produced at the present time.

The following table gives the amount of land under ownership this past year, with its location by township and the available land in each township that could be added to this, could any assurance be given settlers that there would be any water available.

Land under ownership in Ashley Valley.

Township.	Range.	Land under ownership.	Good free land.
		Acres.	*Acres.*
3 S	20 E	2,380	None.
4 S	21 E	18,520	1,000
4 S	22 E	4,120	3,200
5 S	21 E	3,200	640
5 S	22 E	7,600	8,000
5 S	23 E	800	None.
6 S	22 E	1,280	200
Total		37,900	13,040

In view of the fact that out of 49,280 acres, 37,900 are under ownership, this table would not be very convincing as to the great need of water if all the land under ownership was under cultivation. Such, however, is not the case. The following statistics relative to this question are taken from the report of the State board of statistics:

Area under cultivation in Ashley Valley.

Year.	Number of farms.	Total acreage under ownership.	Average size.	Acreage under fence.	Acreage under cultivation.	Average cultivated acreage per farm.
1901	472	37,203	74.58	23,806	13,072	27.69
1902	464	36,408	78.40	27,523	12,257	26.40

The tax roll of the valley carries 29,823 acres of land directly under Ashley Creek. The difference between 29,823 acres and the 37,900 above is represented by what are called "State lands" (sections 2, 16, 32, and 36 in every township). A period of ten years is allowed to elapse before these lands are fully paid for and patented and upon the county tax roll.

The value of an increased water supply to this valley is evident from a comparison between the amount of land under ownership (the greater part of which is absolutely without water for cultivation), which was 37,203 acres in 1901 and 36,408 acres in 1902, and the amount which it is possible to cultivate by the water at hand. This leaves about 24,000 acres which could and would have been cultivated had there been water available. Adding 13,000 acres of good irrigable land yet to be taken gives a grand total of 37,000 acres of as good land as can be found in the West, capable, without a doubt, of supporting a population of at least 25,000 people.

STORAGE POSSIBILITIES

DAM AT MOUTH OF ASHLEY CANYON.

A thorougn examination of the basin of Ashley Creek fails to disclose any reservoir site that could be considered practicable other than the one that is situated, fortunately, at the very mouth of the canyon. The lakes in the mountains are too small to be given any consideration whatever, and in any event the cost of using them is prohibitive.

Briefly, this plan involves the construction of a dam across the mouth of the canyon. This will flood Ashley Canyon for about 2½ miles to a width of from one-fourth to one-half mile, and then spread over into Spring Creek, the basin of which is about 2 miles long by one-half mile wide.

When this reservoir is full, a secondary reservoir is provided by permitting the surplus water to escape from the south side of the Spring Creek side of the reservoir into a natural basin called "Steinaker Draw," capable of storing approximately one-half of the entire water supply of Ashley Creek.

The construction of a rock-fill dam across this opening is facilitated by mountains of good firm sandstone, which rise on both sides very abruptly. This rock could be easily transported in large blocks down grade on cable, and dropped into place from a good height, which would serve to most thoroughly ram it into place, thereby almost certainly insuring against any great settlement of the structure in the future.

The walls of this basin on either side are very abrupt, being almost perpendicular for some distance above the ground. The depth to bed rock is unknown, but it is believed that should this be prohibitive a good solid cemented gravel will be encountered that would be sufficiently firm to serve as foundation for a rock-fill structure.

The distance between abutments in about 750 feet. The abutments are from 350 to 400 feet in height, thereby offering an opportunity for the construction of a dam limited in height only by practical bounds of safe construction.

The dam site in Ashley Canyon is approximately 200 feet above the proposed site in Steinaker Draw, but this latter basin is amply protected by nature, as the divide between Spring Creek and Steinaker Draw is above the crest of any dam that could be constructed in this valley. This is a most admirable provision, in view of the difference in level between the two reservoirs, and will provide a relief to the main reservoir that will eliminate the necessity of providing a spillway near the main structure. The backbone of this ridge, which is not thick, will have to be cut through for a short distance to let the water into this secondary reservoir, and as at the extreme western end of this basin the water will run out to nothing a natural spillway of unlimited capacity is provided 4 miles from the main structure and over 1 mile from the dam site in the opening of Steinaker Draw.

DAM AT STEINAKER DRAW.

At the extreme southern end of Steinaker Draw a dam, not over 75 feet in height, could be built, inclosing this area. Possibly it could be extended to 100 feet, but that might necessitate the construction of a dike at the western end. The natural bank of the south side of this secondary reservoir site seems to be one continuous isolated range of rock in the form of a half circle, running into the foothills of the range at its northern and eastern point, and out to nothing at its western end. This condition provides spillway opportunities most advantageously situated.

The distance from point to point at the opening where the dam would be is 325 feet, and it is contemplated building a rock-fill dam here also, as all the conditions are favorable. Should it be found ultimately that the high cost of this main structure (owing to its length and the depth to which it may be necessary to go for a solid foundation) would prohibit its construction, an alternate proposition is a dam that could be thrown across the opening to Spring Creek basin, which is exceedingly narrow and is equally well supplied with abutments. This latter proposition involves the diversion of the waters of Ashley Creek from their main channel through an artificial channel, heading some distance above in the main channel of the river at about "the gorge," and the construction of a retaining wall in a low saddle between Spring Creek and Ashley basin proper.

Investigation may develop the fact that this alternate proposition is the more feasible.

CONCLUSIONS.

In view of the fact that it has not been possible to obtain some data that are always necessary before conclusions can be reduced to figures, it is hardly safe at this time to even attempt to submit figures as to costs and quantities.

When these sites were visited it was the unanimous opinion that this low saddle between Spring Creek and Ashley basin proper would preclude the acceptance of the alternate site, and from the superficial examination which was made the project originally presented was selected as the most advantageous; but these conclusions are all subject to such modifications as a survey of the sites may show to be necessary.

OPERATIONS IN WASHINGTON.

By T. A. Noble.

During the field season of 1904 investigations in the State of Washington have been progressing in localities which have shown indications of developing feasible projects. Most of the field force has been concentrated on the Palouse project, which seemed most feasible and free from possible complications.

PALOUSE PROJECT.

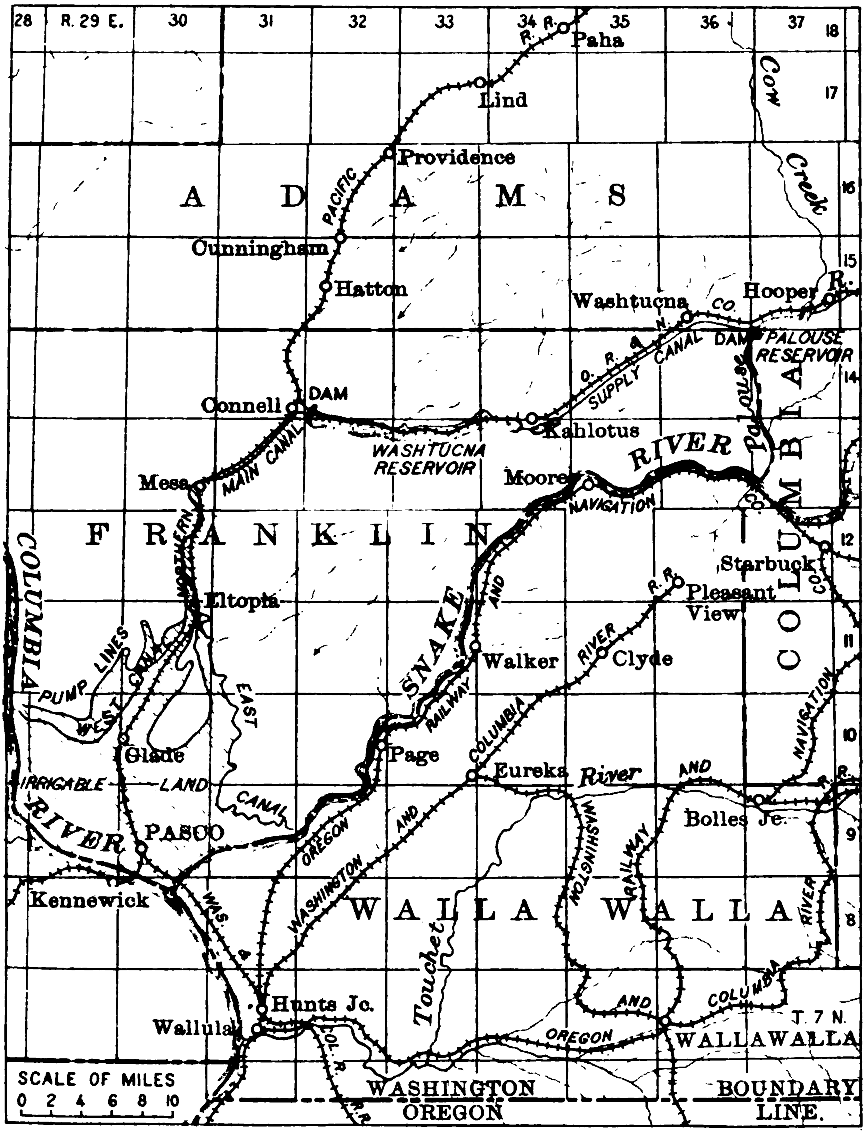
During the fall of 1903 and the winter of 1904 a careful reconnaissance was made of this project to ascertain the advisability of expending the large amount of money necessary to fully determine its feasibility. Barometric surveys were made of the principal reservoir sites to determine their capacities. The water supply was investigated as far as practicable with the information in hand, and the amount of land that could be irrigated determined as nearly as possible without instrumental surveys. Upon the information thus obtained more careful and complete investigations were decided upon to fully determine the feasibility of the plan proposed and its approximate cost.

The project (Pl. LVI) contemplates the irrigation of the portion of the arid lands which lie between Snake and Columbia rivers and between the towns of Connell and Pasco, on the Northern Pacific Railway, and which are sufficiently low to be reached by a canal diverting water from Palouse River near Hooper, Wash.

DIVERSION OF PALOUSE RIVER.

Palouse River varies in volume from 17 to 15,000 second-feet. During a large portion of the year its flow is less than 100 second-feet. Most of the run-off comes in floods when the snow melts. A very small portion of the 2,200 square miles of drainage area is timber land. Most of it is cultivated, hence the fluctuations in discharge are very great. The diverting canal, fortunately, is short, and it is, therefore, feasible to build a canal sufficiently large to divert a portion of the flood waters.

It is proposed to divert the water of Palouse River by headworks located in the vicinity of Hooper.



GENERAL MAP OF THE PROPOSED PALOUSE PROJECT WASHINGTON

DAM SITES.

Two dam sites have been found near Hooper, Wash., on either of which a dam can be founded on solid rock.

The upper site, about 1 mile above Hooper (a station on the line of the Oregon Railroad and Navigation Company), would only be of sufficient height to divert the water from the river into a canal at an elevation of 1,076 feet. This canal would be about 7 miles long, and would run along a rather rough and broken hillside to the summit of the divide between Palouse River Valley and Washtucna Coulee, where a cut would be made to avoid a longer canal line or a higher dam.

The second site is about 7 miles below Hooper, in a narrow gorge 250 feet wide on the bottom at an elevation of 940 feet and 600 feet wide at an elevation of 1,040 feet. By the construction of a dam at this point the 7 miles of canal line would be saved and sufficient storage be provided for all the flood waters required.

Thorough investigation has been made of the relative cost and advantages of these dam sites, with the result that the lower site has been found to involve the least cost of construction and the least engineering difficulties. This dam will be a rock- and gravel-filled structure, about 147 feet high above the foundation. The length on top of the filled portion of the dam will be 1,700 feet. and the length of spillway 815 feet. It is proposed to use the material excavated from the summit for filling in the dam.

CANAL LINE.

The diversion from the lower dam will be by an open cut through the low divide connecting the pool above the dam with the canal line in Washtucna Coulee, the head-gates being located in solid rock near the summit of the cut.

The maximum flood stage in Palouse River during the past seven years was 15,000 second-feet last spring. Allowing 30,000 second-feet as a safe flood limit, the height of discharge over the spillway of the dam, 800 feet long, would be 5 feet. The elevation of the crest of the spillway will be about 1,070 feet.

From the cut through the divide into Washtucna Coulee it is proposed to give the canal a minimum grade for a distance of 7,800 feet to the town of Washtucna.

From Washtucna for a distance of about 10 miles the coulee is flat; for the rest of the distance to Washtucna Lake, a distance of 14 miles, it has 78 feet drop. It will be necessary to maintain the canal at a low grade to save the cost of lining and to take up the fall in the coulee by drops.

WASHTUCNA RESERVOIR.

Washtucna Coulee is the controlling factor of the Palouse project. It is a narrow, dry canyon, sloping toward the west and extending from Palouse River Valley west to the town of Connell, a distance of 35 miles, where it joins Esquatzel Coulee, which runs in a southerly direction and is occupied by the Northern Pacific tracks. The elevation of Washtucna Coulee at the summit of the divide is 1,100 feet. The town of Washtucna occupies the coulee about 3 miles west of Palouse River; at this point the elevation is 1,019 feet.

Near the middle of the coulee, at an elevation of 880 feet, is a small lake, 1¾ miles long and one-fourth mile wide, covering 285 acres. At the western end of this lake, 16 miles distant from Washtucna, is the small town of Kahlotus. The distance from Kahlotus to Connell is about 15 miles. Halfway between Kahlotus and Connell is Sulphur Lake, containing 25 acres, elevation 679 feet, which is the lowest point of the coulee. From this lake to within 1 mile of Connell the bottom of the coulee rises toward the west, forming between Kahlotus and Connell a basin 15 miles long, with its outlet near Connell, 178 feet above the surface of water in Sulphur Lake. This is the proposed reservoir site to be used for storing water diverted from Palouse River.

The elevation of the summit between this reservoir site and Esquatzel Coulee is 857 feet. Through this summit it is proposed to excavate a channel and to draw the water surface down to an elevation of 830 feet, and to build a dam across the divide for raising the surface up to an elevation of 880 feet, giving a storage capacity of 210,000 acre-feet. The maximum height of dam would be 33 feet, and the maximum depth of cut about 30 feet. One hundred and forty-three thousand acre-feet gives sufficient storage for taking care of all the water could have been delivered through a diversion canal from Palouse River during the season of 1903–4. By increasing the height of the dam to 900 feet elevation, or a maximum height of 43 feet, 255,000 acre-feet storage can be obtained.

OUTLET CHANNEL.

From Connell, sloping in a southerly direction, is Esquatzel Coulee, the only feasible outlet from Washtucna reservoir, opening onto the flat lands about Pasco, which it is proposed to irrigate. These coulees are essentially alike and probably at one time formed one continuous watercourse. They vary in width from one-fourth to three-fourths of a mile and are flat on the bottom, with rocky and more or less rugged basaltic walls on either side; these extend to an elevation of 500 to 600 feet above the bottom of the coulee at Washtucna, and to about 100 feet where Esquatzel Coulee ends near Eltopia, where the distribution canals begin. On the hills back of these coulees are most excellent lands, which are cultivated for wheat with indifferent success. In years of sufficient rainfall they raise fair crops. Most of the wheat farmers have to haul the water for domestic purposes and to set aside about 10 per cent of their wheat for feed for their live stock, as hay can not be successfully grown without irrigation. All of these wheat lands are too high to be reached by water from this project.

WATER SUPPLY AND STORAGE.

On Rock Creek, one of the principal branches of Palouse River, is a reservoir site of 76,000 acre-feet capacity, which can be constructed by building a dam 37 feet high across the outlet of Rock Lake and excavating a channel 4 feet deep and 3 miles long for the outlet. This excavation would be in solid rock. The lake contains 2,182 acres at its natural level. The sides are very rocky and precipitous. The total discharge from the lake during the season of 1903–4 was 91,300 acre-feet. The total discharge of Palouse River during the season of 1901–2 was 341,000 acre-feet, the lowest recorded; during 1903–4 the discharge was 637,000 acre-feet. These latter measurements were taken at the point of diversion from Palouse River. To save all of the additional flood waters of Palouse River during a year of average discharge it would be necessary to have a reservoir of at least 75,000 acre-feet capacity within the main branch of Palouse River. The only site so far found that would meet this requirement is just above the town of Winona. Unfortunately, the Oregon Railroad and Navigation Company's tracks occupy this site, and its use would require the rebuilding of about 5 miles of track.

As a further source of water supply it has been found that Hangman Creek can be diverted into the headwaters of Rock Creek. The drainage basin of Hangman Creek joins that of Palouse River on the east and north, and has an area of 273 square miles. It is similar to that of Palouse River in topography and flora, and the stream shows the same radical differences in flow. The point of diversion is about 2 miles below the town of Tekoa, on the main line of the Oregon Railway and Navigation Company. A reservoir site has been found 6 miles upstream from the point of diversion and just inside the Coeur d'Alene Indian Reservation. The capacity of this reservoir, with a 60-foot dam, is 44,000 acre-feet. The measurements of flow of this stream began April 1, 1904, and will not be complete until next summer. The feasibility of the proposed diversion can not, therefore, be definitely determined until that time.

Estimating from the relative flow at Rock Lake and Hangman

Creek for six months past, the run-off of Hangman Creek is 137,000 acre-feet; the maximum discharge is estimated to be 3,500 second-feet; the minimum during the summer of 1904 was 0.53 second-feet. It is estimated that 90,000 acres can be irrigated by gravity. If the duty of water on this land is 3 acre-feet to the acre, 270,000 acre-feet would be required.

CONCLUSIONS.

By storing from 70,000 to 75,000 acre-feet in Rock Lake and from 140,000 to 150,000 acre-feet in Washtucna Coulee, and with a diversion canal of 800 second-feet from Palouse River, 310,000 acre-feet could have been diverted during the season of 1903–4, which was the season of minimum diversion and storage.

By the use of Hangman Creek, in addition to a storage reservoir in the valley of Palouse River for controlling the flood waters during years of maximum discharge, an additional water supply of at least 70,000 acre-feet can be obtained without increasing the capacity of Washtucna reservoir or of the diversion canal. By the construction of a storage reservoir of 75,000 acre-feet capacity in the Palouse River Valley, at least 100,000 acre-feet additional water supply can be obtained, making 480,000 acre-feet available by using practically all of the flow of Hangman Creek and Palouse River.

Along the outlet canal from Washtucna reservoir is considerable fall, which could be utilized for directly pumping this additional water to lands lying between 600 and 750 feet above sea level. These extensions are not now considered advisable, on account of the large cost per acre, but the diversion canal and Washtucna reservoir are designed with this end in view.

INTERFERENCE WITH RAILROAD LINES.

The Washtucna branch of the Oregon Railway and Navigation Company extends through Washtucna Coulee its entire length. Between Kahlotus and Connell the tracks would have to be removed within that portion of the proposed reservoir which would be flooded, a distance of 15 miles. Negotiations are now pending to induce the company to agree to build its road around the north side of the coulee. These negotiations indicate that the road is favorably disposed toward this location and will probably submit a reasonable basis for settlement. Though the Northern Pacific tracks occupy Esquatzel Coulee, it is not expected that there will be any serious interference with their tracks or that there will be any difficulty in inducing the road to arrange for canal crossings. It is expected that in view of the great importance of this project to the Northern Pacific Railway the road will build the canal crossings through this coulee to protect their road and encourage the enterprise.

IRRIGABLE LANDS.

The irrigable lands under the Palouse project differ widely in character and topography. In the upper portion they contain a large proportion of the light soil, about the consistency of flour, that is so prevalent is most extremely arid countries. In the lower portion this is mixed with a large proportion of sand. Shifting sand appears in a few places, but covers no considerable area. This light, sandy soil has been shifted by the winds and forms irregular dunes, making the location of distributing canals somewhat difficult. The cost of excavating for distributing canals will, however, be very reasonable, as no material more difficult to move than gravel has so far been seen on the surface.

PROGRESS OF WORK.

Topographic maps on a scale of 1,000 feet to 1 inch, with contour intervals of 10 feet, have been completed, covering all of the lands that can be irrigated by the plans contemplated for the immediate future and for the territory involved in the location of the canals and reservoirs. The distributing canals have not been laid out and no estimate can be made of their cost. A preliminary estimate of the cost of the entire project was prepared by Christian Andersen, engineer in charge of this work, and submitted to the board of consulting engineers; which met in Spokane on October 17, but there are many minor questions which must be settled before close estimates of cost can be given. The questionable factors seem to be the uncertainty as to the amount of seepage that may occur in Washtucna reservoir, and the possibility of making a reasonable settlement with the many private interests involved.

The present indications are that 90,000 acres can be irrigated without pumping.

PUMPING PLANT.

The main canal from the reservoir has a fall of 200 feet between Connell and Eltopia, in Esquatzel Coulee, along the line of the Northern Pacific Railway. One of the power locations is near Connell and another near Eltopia, and at these points the conditions are favorable for pumping water to elevations not exceeding 100 feet, by power developed from the fall in the main canal, for the irrigation of lands above. It is expected that between 40,000 and 50,000 acres can be reclaimed in this manner.

The cost of irrigating these additional lands would be the expense of additional storage in Palouse River and the cost of pumping and distribution works, the main canals, diversion works, and Washtucna reservoir being of sufficient capacity, as designed, to take care of the additional water required.

OKANOGAN PROJECT.

This project was partly described in the Second Annual Report, pages 488–489.

Field investigations during the field season of 1904, in charge of Charles E. Hewitt, have been completed. It is possible to economically irrigate 11,000 acres of land, all that seems fit for cultivation.

Salmon Creek is the only adequate source of water supply that can be diverted on the land at a reasonable first cost. A record of its discharge has been kept since April, 1903, including two flood seasons. The total discharge, which extends from about May 16 to September 12, one hundred and twenty days, was 31,000 acre-feet in 1903 and 51,000 acre-feet in 1904.

High water begins with melting snows in the surrounding mountains, about the middle of April, and ends in the middle of June, The maximum discharge, so far as recorded, is 487, and the ordinary low-water discharge 20 second-feet.

As intimated in the previous report, it has been found most economical to use a number of small reservoirs with comparatively low dams. Green Lake, being lower than Brown Lake and requiring a much higher dam with a relatively small storage capacity, can be used economically for a limited amount of storage, but is considered as a supplementary storage basin. The only other reservoirs which are accessible from Salmon Creek are Brown Lake, Salmon Lake, and Conconully basin.

In studying the question of water supply and storage it was necessary to keep in mind the following conditions: The water available is barely sufficient for the land to be irrigated; a canal line would have to be built from Salmon Creek to Brown Lake in order to divert the seepage waters from the two reservoirs above the point of diversion; about 2,500 acres near the mouth of Salmon Creek, on both sides of the stream, could not be economically reached by a canal diverting water from Brown Lake, but could be reached by improving the canals now in use and building diversion dams that will divert all of the water flowing in the stream (of these 2,500 acres 1,500 are now being irrigated from private ditches which take the natural low-water flow of Salmon Creek below the proposed main point of diversion); under none of the dam sites does there seem to be any prospect of finding solid rock for the foundation of a high dam; the amount of land to be irrigated is small, and it is essential that the most economical plan consistent with safety and permanence be followed.

Confining the study to the three reservoir sites above mentioned, and bearing in mind that about 18,000 acre-feet storage capacity is required altogether, and that Brown Lake will have to be used in any case, the following synopsis shows the most economical combination.

It is assumed that the cost of the dams is in proportion to their contents.

	Height of dam from ground.	Fill in dam.	Capacity.	Fill per acre-foot of capacity.
	Feet.	*Cubic yards*	*Acre-feet.*	*Cubic yards.*
Conconully basin	65	106,600	12,200	8.74
Brown Lake	35	42,800	7,000	6.11
Total	....	148,400	19,200	7.73
Salmon Lake	40	154,000	13,100	11.76
Brown Lake	35	42,800	7,000	6.11
Total	....	196,800	20,100	9.04
Conconully basin	55	71,690	7,950	9.00
Salmon Lake	10	8,830	4,315	2.05
Brown Lake	35	42,800	7,000	6.11
Total	....	123,320	20,265	6.10

The most economical method to store water in Brown Lake would be to build a 35-foot dam, since to raise the water higher would require a dam at each end of the reservoir.

To raise Salmon Lake higher than 10 feet would flood a country road between Conconully and Loomis, necessitating its relocation, and would also make it necessary to build about 2 miles of canal to divert a portion of Salmon Creek into Salmon Lake.

In all these calculations it is proposed to put in rock-fill dams, with the downstream face of very large fragments of rock with approximate slope of 1¼ to 1 and with a 3 to 1 slope on the upstream side. The upstream face would be covered with well-selected gravel and soil mixture from a slope of 1¼ to 1 to a slope of 2½ to 1 and filled with puddled clay hand mixed with gravel to the proper consistency, from a slope of 2½ to 1 to 3 to 1. On the face of the dam, within the limits of high and low water, the slope would be paved with well-laid loose rubble.

It is not essential that the dam be any tighter than is necessary to make a perfectly safe structure. The foundation of Conconully basin and Salmon Lake dams is probably coarse gravel and bowlders filled with more or less clay and earth to considerable depths. The foundation of the dam at Brown Lake is very hard, cemented gravel, which it is believed will make the dam very tight. For the outlet from this reservoir it is proposed to build a tunnel through the granite ledge on the south slope.

The dam at the point of diversion would be only sufficiently high to divert all the water flowing in the creek within the capacity of the canal and save as much of the underflow as possible.

There are two possible routes for a canal line to divert the water from Salmon Creek to the land to be irrigated. The cost of each would be about the same. One would take the water out near Foster's sawmill and divert it into Brown Lake, and from thence through a coulee for about 2 miles to the highest point of the irrigable lands; the other would take the water out just below Clover and would follow the left bank of Salmon Creek for a distance of 5 miles along a very rough hillside to the same point. As it will be necessary to divert the seepage water into Brown Lake in any case, the first route is most desirable, as the cost of a small canal is but little more than a canal for irrigating all of the land.

There are two alternate methods of diverting from Salmon Creek to Brown Lake, one by 1½ miles of tunnel with a short canal at each end, and one by a canal line about 5½ miles long. All of the latter canal line, with the exception of 3,000 feet, would be in solid rock excavation. The tunnel would be in granite rock and would not have to be lined.

There is no particularly difficult construction in the distribution system. The main canal would be short. Any point in the irrigable lands can be reached from the main canal by branch canals not over 7 miles long.

The irrigable lands consist of 11,000 acres of varying quality, all of which can be successfully cultivated and will raise three crops of alfalfa.

This project contemplates the irrigation of the only body of irrigable land of any considerable size in northern Okanogan County, the balance of the land being either mountainous and covered with a most luxuriant growth of bunch grass or lying out of reach of adequate water supply.

The amount of stock which is fed on these ranges is comparatively limited, as there is not sufficient forage raised to winter the cattle. Eleven thousand acres of irrigated land would therefore enable the settlers, by running stock on the range nine months of the year and feeding three months, to feed three times as much stock as could be fed in more thickly settled communities where the range has been destroyed by excessive feeding.

The average yield of alfalfa is 6 tons per acre. The price during the past two years has varied from $10 to $30 a ton, the latter price being paid when there was practically no hay in the country. Six dollars a ton is a safe estimate of value for hay fed in the stack, or $36 an acre per year. The cost of harvesting this crop is not over $10 an acre per year, leaving $26 an acre a year profit.

All kinds of fruit and vegetables indigenous to a temperate climate can be raised in abundance for home wants and local consumption. On the surrounding hills wheat is successfully raised, but without an increased population can not be marketed, as the cost of haul to the nearest railway, 125 miles, is prohibitive.

BIG BEND PROJECT.

Since the last annual report no additional work has been done on this project, except the establishment of two new gaging stations, one on the Spokane River and the other on Crab Creek near Wilson Creek.

A general classification of the lands under this project will soon be begun. As the area covered is over 3,000,000 acres and the topography somewhat complicated, it will take a careful reconnaissance to determine what land can be irrigated and what it will pay to irrigate. That portion of the area which may be found to be impracticable to irrigate will be restored to entry.

PRIEST RAPIDS PROJECT.

This project contemplates the irrigation of a body of land lying north and east of Columbia River within the area withdrawn under the Big Bend project near Priest Rapids, comprising between 100,000 and 150,000 acres, about 12,000 acres of which are sufficiently low to be irrigated from Columbia River by gravity. It is proposed to irrigate the balance of this land from a direct-acting pumping plant, taking water from above Priest Rapids for power purposes by the same canal that would be used for irrigating the lower lands. The length of the power portion of this canal would be 17 miles, and the effective head at extreme high water about 40 feet. The extreme head to be pumped against would be 400 feet. A recent reconnaissance of the irrigable area by the resident engineer indicates that a reservoir can be constructed within the irrigable area at a reasonable cost. A more careful instrumental survey will be required to definitely determine its capacity.

Most of the lands lie on a bench sloping toward the south from Saddle Mountains. The portion lying near Priest Rapids and along Columbia River is very sandy, but most of the bench land is of the very best character for irrigation.

The Columbia, from below Priest Rapids to Pasco, on the Northern Pacific Railway, and from above Priest Rapids to Trinidad on the Great Northern Railway, is navigable, affording good transportation facilities.

PROPOSED PUMPING PLANT.

It is proposed to use direct-connected units of turbines and compound centrifugal pumps in units of about 500 second-feet capacity each, so designed as to operate at the speed necessary to reach the main distributary canals by pumping.

The topography is particularly favorable for the economical construction of the power and distributary canals.

The feasibility of pumping water to an elevation of 400 feet for irrigation will depend upon the cost of the pumping plant, which can be definitely determined, and the cost of the maintenance, which is uncertain. By reducing the moving parts of the pumps and turbines to one piece for each unit and making the units large the cost can be reduced to a minimum.

There is a very large area in the State which can only be irrigated by the above method. It is important, therefore, that the feasibility of this plan be definitely settled and the limits of its application determined.

At Prosser Falls is a small water-power pumping plant that has been in operation for the past five years, taking water for power and irrigation from Yakima River. Following is a statement by the company of their operating expenses for the year 1903:

Expenses of pumping plant at Prosser Falls.

Pumping	$1,254
Repairs	369
Material	706
Total, not counting interest	2,329

The amount of land irrigated was 1,180 acres, making the cost $1.98 per acre.

By irrigating land to the limit of the capacity of the pumping machinery the cost per acre would be reduced to about $1.50 per year.

The pumping machinery consists of two turbines with vertical shafts operating through a series of bevel gears, horizontal shafts and cranks, and two large directing piston pumps. The water is carried through a large wooden flume to the power house, the end of the flume being enlarged to form the penstock. The average head on the wheels is 12 feet, and the water is pumped to an elevation of 100 feet.

PROGRESS OF WORK.

The work in the field has been confined to a preliminary reconnaissance and a survey and examination of the proposed power-house site to determine the nature of foundation for the heavy machinery.

After this information is obtained it is proposed to determine whether machinery that will meet the above requirements can be obtained and at what cost. It is also proposed that an estimate shall be made of the entire power plant, as this seems to be the controlling factor, before any further instrumental surveys are made.

This project was first surveyed by H. K. Owens, civil engineer, in 1896, for the Northern Pacific Railway, and the results embodied in a report which was submitted to the chief engineer with a request that its feasibility receive further investigation.

Lands under this project along both banks of Columbia River were withdrawn on July 26, 1904, under the first form of withdrawal to protect the water power and for town-site purposes during investigation.

RECONNAISSANCE.

A reconnaissance survey was made during March and April to ascertain the feasibility of taking water from Columbia River above Priest Rapids, and conducting it by a canal line on the right bank to irrigate a large body of land between Yakima and Columbia rivers and Rattlesnake Hills on the west.

The survey showed that about 34,000 acres of good land could be irrigated in this way, but as the canal would be along a very broken and rocky hillside for 17 miles, the scheme would probably be too expensive to warrant any additional investigation. It is probable, however, that this large body of land can be partly irrigated from the Priest Rapids pumping plant. The feasibility of the project, therefore, will depend upon the results of the Priest Rapids investigation.

YAKIMA EXAMINATION.[a]

Nowhere in the State of Washington has irrigation been practiced so long, or so extensively, or have matters pertaining to irrigation reached a higher state of development, than in Yakima Valley. Notwithstanding this fact about three-fourths of the land in this valley is still unirrigated, which, with the storage facilities at hand, can be considered irrigable.

Yakima Valley is crossed by a series of high east-west ridges, which are cut at various intervals by Yakima River. These ridges are rough and covered with stones and outcropping ledges of a basaltic nature, and are, moreover, above any source of irrigation. They will probably never be used for other than grazing purposes. The good land is located in the valleys between the ridges.

These lands are dependent for their irrigation upon Yakima

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[a] From report by George H. Bliss.

River and its principal tributary, Naches River, which when it joins the Yakima has already been increased by the flow of Tieton River. From these three rivers and storage reservoirs that can be created upon them must come the water to irrigate the vast amount of dry land in the Yakima Valley.

This land is for the most part of the very finest quality. The soil is of volcanic origin, and of about the consistency of flour. It is now, with a few exceptions, thickly covered with sagebrush. When water is applied the land becomes highly productive, large and very profitable crops of fruit, alfalfa, hops, and grain are raised.

Investigations in Yakima Valley were begun on April 12, 1904, under charge of George H. Bliss, assistant engineer. The investigations have included the following:

(1) Thorough hydrographic measurements of the sources of water supply and the amount of water used by the various canals taking water out of Yakima River and its tributaries.

(2) A reconnaissance to determine approximately the proportion of good land that can be irrigated by the principal and most feasible schemes.

(3) The compilation of all available information regarding each of these schemes to determine the location of proposed canal lines and of all canals already in use, the construction of maps showing all existing and proposed canals, and the classification of lands under them as to character and ownership.

As a result of this investigation it has been found that there are two feasible schemes of considerable magnitude, viz, the Tieton-Cowiche scheme, to irrigate about 40,000 acres lying from 10 to 20 miles west of North Yakima, from Tieton River; and the Ledbetter scheme, to irrigate about 100,000 acres of land lying along the lower Yakima Valley below Kiona. The lands under the former lie at between 1,500 and 2,000 feet elevation and those of the latter at between 350 and 600 feet. Both are dependent upon storage for water supply.

Four proposed canal lines and lands covered by them were examined, such surveys as were possible being made without maintaining large parties in the field. These canal lines will be known in this report as the High-line, Naches and Columbia River, Tieton-Cowiche, and Ledbetter canals.

An extremely small proportion of the land underlying these proposed canals is vacant Government land, except in the Yakima Indian Reservation, and of this a large amount is second if not third-class land. A considerable portion of the first-class land has been filed upon as homesteads and desert claims, for which final certificates have not been issued. Another small proportion of the land under these canals may be considered as private, but the greatest percentage of land belongs to either the Northern Pacific Railroad or to the State.

The irrigating season in Yakima Valley may be considered as extending from April 15 to October 15. After the third cutting of alfalfa during the latter part of August, however, the amount of water used for irrigation is materially decreased, as there is after that date usually only a last irrigation of orchards and a wetting or two of newly seeded land.

WATER SUPPLY.

Besides examining the various canal lines mentioned and the lands under them, a very careful study has been made during the summer of the flow of Yakima River and its tributaries.

Not only have daily gage readings at the former stations on the Yakima, Naches, and Tieton been continued, but these streams have been rerated by a series of very careful discharge measurements taken at intervals of one-half foot vertically. A new and complete rating table has been established for each stream, as well as for the 29 principal canals taking water from them. From the tables thus formed the flow of each or all of the canals can be determined during the irrigating season.

Miscellaneous measurements have been taken to determine the low flow of the rivers at critical points, and also upon some of the large canals to determine the seepage and wastage.

The rating of the streams from Clealum, Kachess, and Keechelus lakes, at the head of Yakima River, has been completed by a series of very careful discharge measurements and a rating table formed. Miscellaneous measurements have also been obtained upon the North and South forks of Tieton River, at the reservoir site in McAllister's meadows, which tend to show a considerable underground flow at the regular station maintained upon the Tieton River since 1902. Miscellaneous measurements were also made at the mouth of Bumping Lake, American River, Naches River above Bumping River, and Rattlesnake Creek during the low stages.

Whichever, if any, of the proposed canals are constructed, most of the water supply must come from Yakima, Naches, and Tieton rivers and their branches between October 15 and July 1 of the following year. The reservoirs in which this water can be stored are Lake Keechelus, Lake Kachess, and Lake Clealum, all at the head of the Yakima, Bumping Lake at the head of the Naches, and McAllister's meadows upon the Tieton.

The feasibility of constructing dams of sufficient height to store the amount of water required has not been determined. At the mouth of Lake Keechelus a timber dam is in the process of construction by the Cascade Lumber Company, to be used for rafting purposes, and at the mouth of Lake Kachess a fairly substantial rock-filled dam has been constructed by the Cascade Canal Company to store water for the irrigation of lands near Ellensburg. This last dam has raised the level of the lake about 8 feet above low-water mark. The flow from the remaining 3 reservoir sites remains as yet unimpeded.

From the time the water leaves these lakes almost to the point where the Yakima finally discharges into the Columbia the flow of the rivers is being diminished by numerous and, in some cases, large canals, the water from which is being used for irrigating, manufacturing, and domestic purposes.

Although the small creeks which lead into these rivers, especially those entering the Yakima, discharge a considerable amount of water during the flood season, their flow during the irrigation season is practically nothing and must be disregarded for irrigating purposes, other than to supply the small canals already deriving water from them. The flood water from these creeks, so far as is at present known, can not be stored in large quantities.

EXISTING CANALS.

During the season of 1904 a study has been made of canals taking water from Yakima, Naches, and Tieton rivers (Pl. LVII). No discharge measurements or gage-height readings have been obtained on canals of a capacity of less than 3 second-feet, such being lumped together as small ditches.

Practically no water was taken from Yakima River above the mouth of Clealum River during the season of 1904. Water was stored in Lake Kachess by the Cascade Canal Company to the depth of 8 feet, but up to this time its irrigating canal is not completed and no water has been used.

Between the mouth of Clealum River and Ellensburg the four canals heading in Yakima River are the Cascade canal, the West Kittitas canal, the town canal at Ellensburg, and the Olsen, or mill, ditch. The first is not yet completed, and no water has been used for irrigation. It has under it 16,000 acres, with no extension contemplated. Allowing 1 cubic foot per 160 acres, with 25 per cent for loss of water in transmission, 125 second-feet would be required.

Average flow of canals between Clealum River and Ellensburg, Wash.

	Second-feet.
Cascade canal, capacity	125
West Kittitas canal, average flow season 1904	52
Town canal (Ellensburg), average flow season 1904	116
Olsen or Mill ditch, average flow season 1904	14
Total	307

Below Ellensburg and above Naches River there are only 2 canals of consequence taking water from Yakima River. They are the Selah-Moxee canal on the left bank and the Taylor canal on the right.

Average flow of canals in Yakima Valley between Ellensburg and Naches River, 1904.

	Second-feet.
Selah-Moxee canal	74.9
Taylor canal	11
Private ditches	3
Total	88.9

The 4 canals heading in Yakima River between Naches River and Atanum Creek all take water from the left bank in the Moxee Valley; they are the Moxee and the Hubbard of the Moxee Company, the Fowler, and the Granger.

Average flow of canals in Yakima Valley between Naches River and Atanum Creek, 1904.

	Second-feet.
Moxee	21.1
Hubbard	24.8
Fowler	25.9
Granger	18
Total	89.8

Below Atanum Creek the 12 canals taking water from the Yakima River are the New Reservation and Old Reservation canals, the Sunnyside canal of the Washington Irrigation Company, the Gilbert, the Hatch, and a small Government canal near Toppenish, the Prosser Falls and Ledbetter canals at Prosser, the Kiona and Kennewick canals of the Northern Pacific Irrigation Company, and the Kiona Water Supply and the Grosscups canals near Kiona.

Average flow of canals in Yakima Valley below Atanum Creek.

	Second-feet.
New Reservation canal	56.4
Old Reservation canal	130
Sunnyside canal	54.7
Hatch canal	8
Gilbert canal	35.1
Government canal (Toppenish)	10
Prosser Falls canal	[a] 205
Ledbetter canal	2
Kiona canal	19.9
Kennewick canal	107
Grosscups canal	([c])
Kiona Water Supply Company	[b] 19
Total	1,139

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[a] Approximately 195 second-feet of this amount flows back into the river at the power house.

[b] Approximately 75 per cent of this amount flows back into the river at foot of canal.

[c] Not completed during 1904.

There is only one canal of consequence taking water from Tieton River, and that is a small canal of about 5 second-feet capacity, which heads in the river on the left bank, about 3 miles above its mouth. It is maintained by Messrs. Sinclair and Cobb. The water of the Tieton, therefore, flows almost unutilized into Naches River.

Of the canals heading in the Naches above Tieton River, only one has a carrying capacity of any consequence. This is the Selah Valley canal, which heads in the left bank just above the mouth of the Tieton. There are several small canals, the combined flow of which would probably not exceed 15 second-feet.

Average flow of canals heading in Naches River above Tieton River in 1904.

	Second-feet.
Selah Valley canal	72
Small canals (combined)	15
Total	87

Below Tieton River and above Cowiche Creek, the canals taking water from Naches River, and their average flow for the season of 1904, are as follows:

Average flow of canals heading in Naches River, between Tieton River and Cowiche Creek, 1904.

LEFT OR NORTH BANK.

	Second-feet.
Wapatox canal	31.2
Gleed (Naches Canal Co.)	54.2
Kelley, Lowery, Clark, and Moursey canals	[a] 56
White & Leach, McCormick, Shearer, Chapman, and other canals	[a] 19
Total	160.4

RIGHT OR SOUTH BANK.

	Second-feet.
Yakima Valley or Condon ditch	57.4
Naches-Cowiche canal [b]	38.4
Cox canal	4
Upper Scott canal	7
Lower Scott canal	10
Fortune canal	7
Laswell canal	10
Scheuler-Rhodenbach canal	6
Total	139.8

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[a] These canals all receive seepage and waste water from large canals above.

[b] Up to June 15 the Naches-Cowiche canal gets its water from the Cowiche Creek.

The canals taking water from Naches River below Cowiche Creek are all on the right or south bank, as follows:

Average flow of canals taking water from Naches River below Cowiche Creek, 1904.

	Second-feet.
Power canal [a]	183
Union canal (both head gates)	36.6
Broadgauge canal [b]	11.8
Shanno canal [b]	24.4
Town canal of North Yakima	12.5
Total	268

CANAL LINE SURVEYS.

The surveys mentioned above, namely, the Natches and Columbia River, Tieton-Cowiche, and Ledbetter, constitute all the proposed schemes in the Yakima region, which, on account of the amount and nature of the land coming under them and the general conditions, it was thought advisable to investigate at the present time.

The surveys and calculations pertaining to them are not yet fully completed, especially in the case of Ledbetter canal. All figures, therefore, in regard to the amount and nature of land coming under the proposed canals, as well as the storage facilities at hand, must be regarded as approximate.

NACHES AND COLUMBIA RIVER CANAL.

This would have its intake upon the left bank of Naches River, the headworks being located about 3½ miles below the mouth of Tieton River, in sec. 5, T. 14 N., R. 17 E. This proposed canal was originally surveyed by H. K. Owens in 1895, under the direction of the State arid land commission.

The canal for the first 15 miles would follow the southern slope of the ridge separating the Naches from Wenas Valley; thence it would pass to the northern slope of the same ridge and continue to the 18-mile mark, where, at Selah or North Gap, it would cross Yakima River by a large inverted siphon. After crossing Yakima River the proposed canal would circle around Moxee Valley to a point in sec. 19, T. 12 N., R. 21 E., where by a tunnel 6,100 feet long it would pass to the south slope of Rattlesnake Range.

In the pass between Moxee and Rattlesnake valleys a point exists sufficiently low to conduct the water through without tunneling. The calculations to determine whether or not it would be less expensive to tunnel or to conduct the very large amount of water that will be required through a distance of 13 miles to avoid tunneling have not been completed. During nearly all of these 13 additional miles good land is covered, but it probably will be found more economical to cover this by means of a lateral of smaller flow.

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[a] About 125 second-feet of this amount wastes into Yakima River, 1 mile below the mouth of Naches River.

[b] Both the Shanno and Broadgauge canals received a greater part of their water from the flow of the power canal, and are included in the 187 second-feet.

After passing to the south side of Rattlesnake Mountains the canal continues along that slope, covering a large and very fertile area of land lying above the Sunnyside canal of the Washington Irrigation Company. At the eastern extremity of Rattlesnake Mountains, about 6 miles north of Kiona, it circles to the north slope of these mountains and commands an extremely large amount of land lying between Columbia River and Rattlesnake Mountains north of the Yakima. The soil is very deep and would be extremely productive should water be applied to it.

The canal would terminate near Columbia River at the end of the 140-mile mark. All the land included under this canal lies under the high-line canal. It would, however, be about 50 miles shorter, and probably the land under it requires more water than is available.

WATER SUPPLY.

This proposed canal has the advantage over the high-line canal of heading in Naches River below the mouth of the Tieton, where there can be obtained not only all the water that would be available for the high-line canal, but the additional water that can be stored at McAllister's meadows on Tieton River.

Under this canal are 406,000 acres of first and second class land. Allowing 1 second-foot per 160 acres and 25 per cent for loss in transmission, 3,200 second-feet of water would be required to irrigate all the land.

The average flow of Naches River into the Yakima, after all the canals upon the Naches and Tieton have been satisfied, for the last five years (1900 to 1904, inclusive) during the irrigating season, has been as follows:

Average flow of Naches River during irrigation season.

	Second-feet.
April	3,287
May	4,856
June	4,213
July	1,829
August	649
September	423
October	843

For four months during the irrigation season stored water in varying amount would be used. The storage reservoirs available are Bumping Lake, with a capacity of 22,300 acre-feet, and McAllister's meadows, with a capacity of 35,000 acre-feet. The height of proposed dam is 110 feet, and the total storage capacity of the two reservoirs is 57,300 acre-feet.

From these figures it can be seen that this scheme as a whole, like the high-line canal, is impracticable. There is without doubt water enough available, with storage, to irrigate the small areas of land remaining in the Naches, Selah, and Moxee valleys, as well as a portion of that in Rattlesnake Valley above the Sunnyside canal, but owing to the long stretch of canal construction for the amount of land irrigated, as well as the expense of constructing certain parts of it, it will probably be found more advantageous as well as economical to utilize the available water supply for either the Tieton-Cowiche or the Ledbetter canals.

IRRIGABLE LANDS.

The amount and character of the land under the Naches and Columbia Valley canal is as follows:

The amount of land in Naches Valley that this canal would be used to irrigate is extremely small, not exceeding 500 acres, mostly of first-class land. In Selah Valley, west of Yakima River, between the low ridge north of Naches River and Wenas Creek, are about 6,500 acres of first-class land that could be irrigated from such a source. Upon the east side of Yakima River, a lateral around Yakima Ridge to Selah Creek, would cover in addition about 6,000 acres of first-class land and 1,000 acres of second-class land in Selah Valley, making a total of 12,500 acres of first-class and 1,000 acres of second-class land coming under this canal.

In Moxee Valley above the Selah-Moxee canal about 13,000 acres of the very best land could be watered from this canal. After crossing the Moxee Pass to the south side of Rattlesnake Range, the canal would parallel the high-line canal and the Sunnyside canal of the Washington Irrigation Company, which lies about midway between the two at an average of 4 miles from the latter. The arid land thus controlled beyond the eastern extremity of Rattlesnake Range, near Kiona, is all first class and of the best quality, lying well for irrigation. In amount it is approximately 110,000 acres, about 12,000 acres of which lie under the proposed extension of the Sunnyside canal.

North and east of Rattlesnake Range, between this range and Columbia River, the land gained would be mostly first class, 243,000 acres, and second class, 26,000 acres. Of this 200,000 acres comes under the proposed extension of the Sunnyside and Kiona canals.

Acreage under Naches and Columbia River canal.

	Acres.
First-class land	379,000
Second-class land	27,000
Third-class land	
Total	406,000

Of this, 212,000 acres, nearly all first-class land, comes under the proposed extension of the Sunnyside and Kiona canals.

Of the 379,000 acres of first-class land, 8,000 are private, 207,000 acres railroad, 135,000 acres State, and 29,000 acres Government. Of the latter, 7,500 acres is vacant land. Of the 27,000 acres of second-class land, none is private, 13,600 acres are Government, 3,900 acres State, and 9,500 acres railroad.

FEASIBILITY.

The two principal engineering features which would determine the practicability of this canal from a structural standpoint are the crossing of Yakima River by inverted siphon at or north of Selah Gap, and the 6,100-foot tunnel beginning in sec. 19, T. 12 N., R. 21 E. It is probable that such a crossing will be found practicable. The tunnel will be through material easily excavated, and can probably be constructed without unwarrantable expense. Although the cost of construction at both of these places may be found high, the average cost per mile of the canal built would undoubtedly be small, as the canal for the greater part of its length would be excavated along the gentle side-hill slopes where construction work would be easy and inexpensive.

At the point of diversion a fairly good site exists for a diversion weir. The river is 300 feet wide at this point and its bed is covered with large bowlders, which in case of construction would have to be excavated to smaller gravel.

TIETON-COWICHE CANAL.

This canal contemplates taking water from Tieton River where that stream is crossed by the 2,250-foot contour, at a point about 9½ miles above its mouth, and conveying it around the steep and irregular bluff on the south bank of that river to a point in sec. 10, T. 14 N., R. 16 E., where by a tunnel about 2,000 feet long it is proposed to cross onto the easy slopes of the Cowiche bench land.

From the mouth of the tunnel the canal follows the 2,000-foot contour to a point in sec. 30, T. 14 N., R. 17 E., where it may be found less expensive to cross Cowiche Creek by inverted siphon than to follow the contour around for a distance of about 4 miles, since the land to be gained by following the contour is mostly under irrigation from Cowiche Creek.

After crossing the creek the canal follows an easy slope around the western extremities of Wide Hollow, and finally discharges into Atanum Creek in sec. 17, T. 12 N., R. 16 E.

Another proposal in connection with this scheme is to cross Atanum Creek at grade and continue the canal along the north side of Atanum Ridge until near sec. 15, T. 12 N., R. 18 E., where it would cross to the south side of this ridge and would follow easy side-hill slopes around the Yakima Indian Reservation until it terminated at Toppenish Creek in sec. 14, T. 11 N., R. 16 E. By this extension about 42,000 additional acres of reservation land of the very best quality, which lie above any canal now constructed, could be irrigated. It is probable, however, that this land in the reservation can be irrigated less expensively from other sources.

WATER SUPPLY.

The amount of water required to irrigate the 40,000 acres under the canal as proposed to Atanum Creek would probably not exceed 400 second-feet after due allowance is made for water lost in transmission.

The average flow of Tieton River at the point of diversion during the irrigation season for the past three years has been as follows:

Average flow of Tieton River in irrigating season.

	Second-feet.
April	1,047
May	1,507
June	1,648
July	849
August	442
September	338
October	383

The lowest flow that has occurred during the last three years was 250 second-feet.

The irrigating season is closed in this valley after October 15, and no great amount of water is used after September 15. The time, therefore, during which, under ordinary circumstances, stored water would be used is from the end of July to the middle of September, a period of about forty-five days.

Assuming that from the last of July all the water flowing through the canal (400 second-feet) would be stored water, a storage reservoir of 35,000 acre-feet capacity could maintain such a flow for forty-four days.

The proposed canal to Atanum Creek is undoubtedly feasible in every respect. For the irrigation of the additional 42,000 acres in the Yakima Indian Reservation it will probably be found that not sufficient water exists from this source, even if irrigation from it were feasible. The reservoir of 22,300 acre-feet capacity at Bumping Lake could be utilized to supply any deficiency during the low stage in existing canals.

IRRIGABLE LAND.

The amount and character of the land controlled by the proposed Tieton-Cowiche canal is as follows:

Classification of land controlled by proposed Tieton-Cowiche Canal.

	North and east of North Fork of Cowiche Creek.	Between the North and South forks of Cowiche Creek.	South of the South Fork of Cowiche Creek to Atanum Creek.	Summary.
	Acres.	*Acres.*	*Acres.*	*Acres.*
First class	10,000	1,000	25,000	36,000
Second class	1,000	None.	7,500	8,500
Third class	3,500	None.	None.	3,500
Total				48,000

This is exclusive of the 42,000 acres of reservation land that could be covered by an extension of the proposed canal across Atanum Creek.

Of this 48,000 acres 25,000 acres are under private ownership or contract from railroad, 7,500 acres are railroad land grant, 3,500 acres are State land grant, 12,000 acres are Government land. All but 3,000 acres of this last have been filed upon, but final certificates have not been granted.

FEASIBILITY.

The chief engineering difficulty in constructing this canal will be in the first 8 miles, which will lie mostly on rocky hillsides along the right bank of Tieton River, and in a tunnel about 2,000 feet long between the valleys of Tieton River and Cowiche Creek. The balance of the canal construction would be comparatively easy and inexpensive.

LEDBETTER CANAL.

The fourth and last proposed canal line investigated was the Ledbetter canal. Construction work at intervals along about 20 miles of this canal has already been executed. Several years ago, owing, it is understood, to lack of capital, work upon the canal was discontinued, and the work already accomplished was allowed to fall into a dilapidated condition. The first 2 or 3 miles, however, are kept in repair, it is understood, by farmers, who use the water from the canal without cost.

By this canal it is proposed to take water from Yakima River at the head of Prosser Falls, opposite the Prosser Falls Pumping Plant, at Prosser, Wash., or at a point in sec. 11, T. 8 N., R. 24 E. The canal follows the bank of the Yakima River until, at the 18-mile mark, in sec. 1, T. 9 N., R. 26 E., it divides, part of the water crossing Yakima River by an inverted siphon and part continuing along the east bank and by a series of distributing laterals covering fertile land lying between Columbia River and Rattlesnake Mountain Range. That part of the total flow of the canal which crosses the Yakima near Kiona continues parallel to the Kennewick canal, at an average distance of 2 miles, until it finally terminates near Columbia River in T. 7 N., R. 31 E.

WATER SUPPLY.

Under this canal there are approximately 150,000 acres, to irrigate all of which 2,500 second-feet of water would be required, including the allowance made for seepage, etc.

During the irrigating season of 1904 measurements were taken at Prosser to determine the flow of the Yakima River, which was found to be as follows:

Flow, in second-feet, of Yakima River at Prosser.

Month.	Minimum.	Average.
April	2,400	16,800
May	8,000	13,800
June	7,700	11,500
July	1,400	5,100
August	60	450
September	40	65
October	140	290

The above figures represent the flow of the river at the head of Prosser Falls that could be delivered into the intake of the Ledbetter canal, not including the amount delivered to the Prosser Falls Irrigation Company's flume.

From the above figures it will be seen that it would only be necessary to use stored water for approximately two and one-half months, or from the last of July until the middle of October.

The reservoirs available for the storage of water are the following:

Reservoirs available for storage of water for Ledbetter Canal.

Reservoir.	Area.	Height of dam.	Capacity.
	Acres.	*Feet.*	*Acre-feet.*
Lake Keechelus [a]	2,180	46	72,800
Lake Kachess [a]	3,960	30	74,900
Lake Clealum [a]	3,743	78	219,700
McAllisters Meadows [a]	1,025	110	34,500
Bumping Lake	631	25	22,300
Total			424,200

[a] Figures taken from surveys made in 1903 by Yakima Development Company.

Assuming that all the water used after July 31 would be stored water, a reservoir capacity of about 335,000 acre-feet would be required to furnish a flow of 2,500 second-feet up to October 15.

IRRIGABLE LANDS.

The land which lies between the Kennewick canal and the proposed canal is of very good quality, and can be cultivated immediately when water can be applied to it. That controlled by the first 12 miles of the canal is more or less scabby and irregular, and has been termed second class; of this there are 1,500 acres. Between the 12- and 18-mile marks, where the water of the canal is divided and part is carried to the east bank of the Yakima, near Kiona, about 700 acres of first-class land is covered by the canal; the land lying between the Kennewick canal and the proposed canal, comprising 24,500 acres, is all first class.

That portion of the total flow of the canal which remains upon the west bank of Yakima River at the end of the eighteenth mile passes along parallel to the river and about three-fourths mile therefrom, and until the twenty-fourth mile is reached, covers about 800 acres additional of first-class land, all of which lies above the Kiona canal. At the end of the twenty-fourth mile the proposed canal begins to control arid land of the very best quality in large quantities.

By a system of distributing canals and laterals 113,000 acres, nearly all of first-class land, lying west of Columbia River, between it and Rattlesnake Range, is covered. All of this land is above any existing canal, but all lies under the proposed extension of the Sunnyside canal. Besides this there are 12,000 acres of second- and third-class land lying in Columbia Valley.

Of the first-class land which will come under the proposed canal there is a total of 139,000 acres, of which 9,000 acres are private, 38,000 acres State, 63,000 acres Northern Pacific Railroad, 7,000 acres Northern Pacific Irrigation Company, and 22,000 acres Government lands which have been filed upon but for which no final certificate has been issued.

Of the 12,000 acres of second and third class land 2,000 acres are Government land, filed upon but not acquired; 6,000 acres railroad land, and 4,000 acres vacant Government land, a total of 12,000 acres.

FEASIBILITY.

The intake of this canal would be located at the head of Prosser Falls, opposite the intake of the Prosser Falls Irrigation Company's flume. At this point a good place exists for a diversion weir. One of combination concrete and steel skeleton construction was built by the Prosser Falls Irrigation Company during the season of 1904, for the purpose of diverting the low flow of the river into their flume.

From a structural standpoint the Ledbetter canal is undoubtedly feasible, and for nearly its entire length could be constructed at reasonable cost. For the most part it would be through soil, the excavating of which would be inexpensive. The crossing of Yakima River by inverted siphon for a part of the total flow of the canal would be the chief engineering difficulty, but as the amount of water required to irrigate the 24,500 acres of land lying under the canal upon the east side of the Yakima would not exceed 300 second-feet, the pipes required for crossing would not be very large and the head light, and the cost of construction would not be excessive. The average cost per acre would undoubtedly be reasonable, while the area of land to be covered is large and very fertile.

The project seems entirely feasible both topographically and hydrographically. Surveys are still in progress to determine more closely the quantity and quality of the land under this canal, and all figures given above pertaining to these subjects must be considered approximate.

It is questionable whether the United States has the right to turn the stored waters into the stream and take them out at Prosser Falls. Such right may, however, be granted at the next session of the State legislature.

OPERATIONS IN WYOMING.

By Jeremiah Ahern.

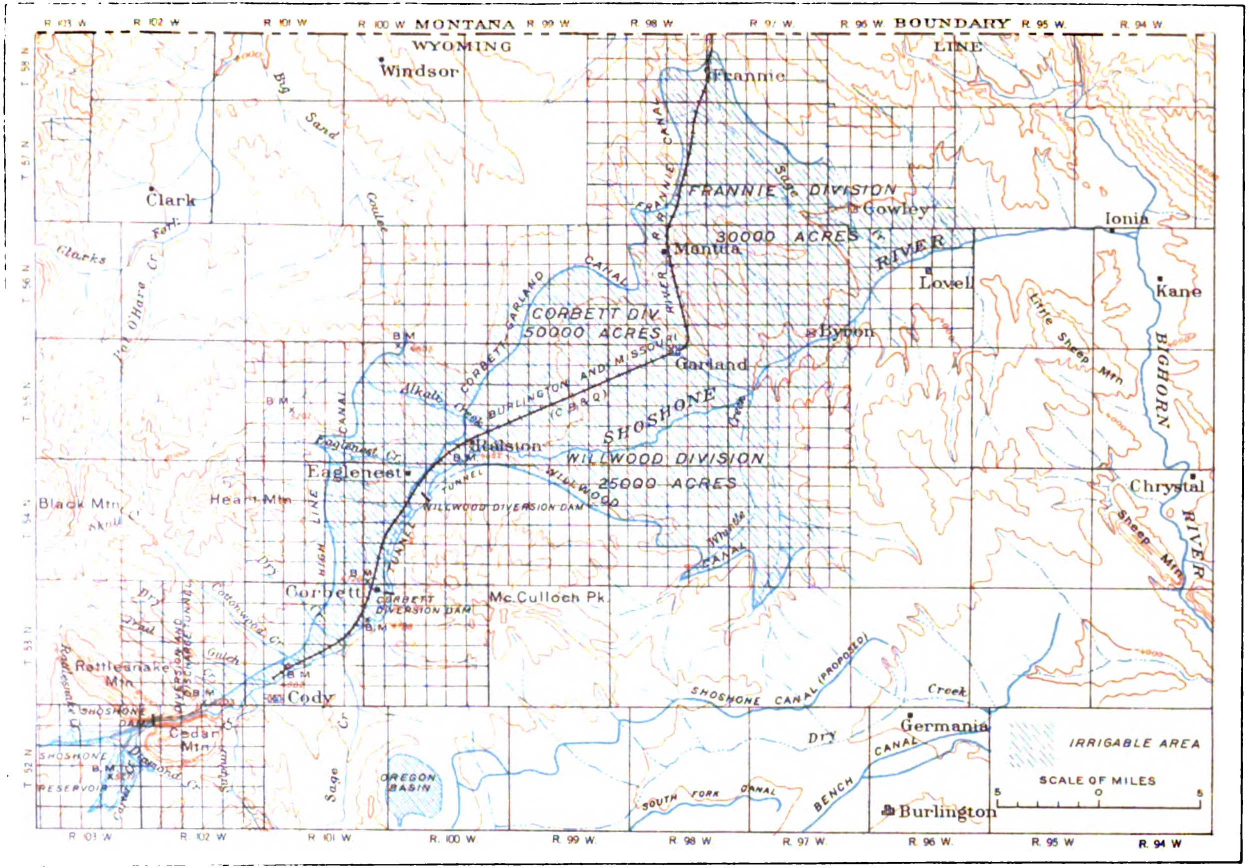
SHOSHONE PROJECT.

Investigations of the Shoshone project (Pl. LVIII) began in 1903 and were described generally in the Second Annual Report of the Reclamation Service, pages 507–510.

On December 29, 1903, the subject of the relinquishment of the land segregated by the State under the Carey Act was taken up by correspondence with Governor Chatterton, of Wyoming, and later all of the rights of the State in the land were relinquished to the Secretary of the Interior by the State land board.

Preliminary plans and estimates, made early in 1904, based on the investigation of 1903, showed that approximately 93,000 acres of first-class land could probably be reclaimed at a probable cost of about $25 per acre. These plans were passed upon by a board of engineers, and on February 10, 1904, the Secretary of the Interior set aside $2,250,000 of the reclamation fund for the construction of the project, "*Provided*, That satisfactory rights to land and water be secured, and provided that further consideration of details on the ground, by consulting engineers, results in favorable reports." On February 13, 1904, Col. W. F. Cody, as the surviving partner of Cody & Salisbury, transferred to the Secretary of the Interior the right of Cody & Salisbury to appropriate water of Shoshone River, for the reclamation of the land segregated by the State. On March 5, 1904, an application for a permit to construct a reservoir and to store 159,500 acre-feet of the water of Shoshone River was filed in the office of the State engineer of Wyoming.

On March 28, 1904, an enlargement application of the Cody and Salisbury permit, covering lands additional to the lands segregated by the State, was filed in the same office. Both applications were filed for and on behalf of the United States. In April, 1904, H. N. Savage and W. H. Sanders, consulting engineers, examined the preliminary plans on the ground and recommended some changes in the design of the dam, and that construction of the project begin at an early date, provided borings at the dam site showed that the foundation was satisfactory.



A. HOEN & CO. BALTIMORE

GENERAL MAP OF SHOSHONE PROJECT, WYOMING.

In May, 1904, field operations were resumed and are still under way. These operations consist of the location of conduit lines, topographic surveys of additional lands that may be reclaimed under the project, borings at the dam site to determine the depth to bed rock, digging of test pits along conduit lines, designing of various structures, construction of wagon roads (Pl. LIX, *A*), telephone lines, houses for headquarters, and a preliminary classification of the irrigable land.

IRRIGABLE AREA.

Surveys made during 1904 show that it is feasible to reclaim an area of approximately 30,000 acres additional to the area surveyed in 1903. Most of this land lies northeast of the town of Garland, along Polecat and Sage creeks, nearly all of it being first-class land. This, together with land lying above the canal line which may be reclaimed by pumping, will bring the total area of irrigable land up to about 125,000 acres. On the south side of Shoshone River, opposite the railroad station at Ralston, is the 24,000 acres of first-class land segregated by the State under the Carey Act, which may be relinquished to the Secretary of the Interior.

PLANS FOR RECLAMATION.

The project contemplates the storage and diversion of a portion of the surplus water of Shoshone River for the reclamation of public land on the north side of the river, extending from the mouth of Shoshone Canyon to Frannie station on the Burlington Railroad, a distance of about 50 miles, and covering an area of approximately 282,000 acres. At the head of Shoshone Canyon a dam of concrete masonry, arched in plan, will be constructed.

The dam site (Pl. LIX, *B*) is 75 feet wide on the bottom of the channel, and 200 feet wide at an elevation of 240 feet, the proposed height of the dam above the river bed. The walls of the canyon at the dam site are of granite. A dam of the above height will give a storage capacity of 456,000 acre-feet above the intake of the outlet tunnel. A spillway 250 feet in length and connecting with a tunnel through the granite will be constructed for the discharge of surplus flood water.

The table following shows the capacity of the reservoir site at different contours.

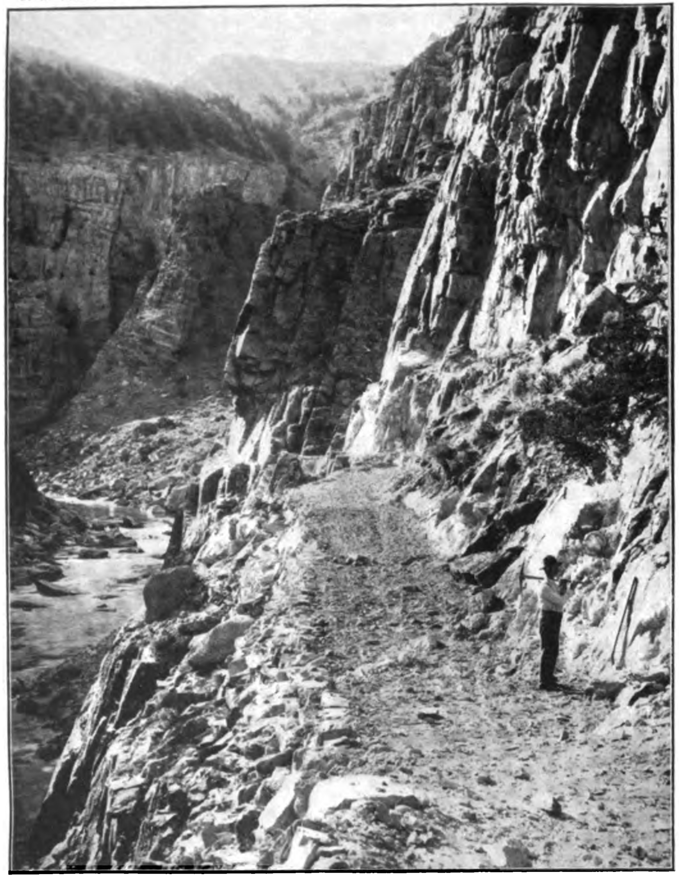
Capacity of Shoshone reservoir.

Contour.	Area.	Capacity between contours.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
5,140	2	....	....
5,150	18	100	100
5,160	21	194	295
5,170	59	400	696
5,180	121	902	1,598
5,190	184	1,522	3,120
5,200	316	2,498	5,618
5,210	463	3,897	9,514
5,220	666	5,646	15,161
5,230	886	7,759	22,920
5,240	1,181	10,336	33,256
5,250	1,458	13,196	46,452
5,260	1,785	16,214	62,666
5,270	2,109	19,470	82,136
5,280	2,444	22,762	104,898
5,290	2,869	26,564	131,462
5,300	3,363	31,161	162,623
5,310	3,820	35,916	198,538
5,320	4,317	40,686	239,224
5,330	4,845	45,812	285,037
5,340	5,377	51,112	336,150
5,350	6,018	56,976	393,126
[a] 5,360	6,604	63,110	456,000

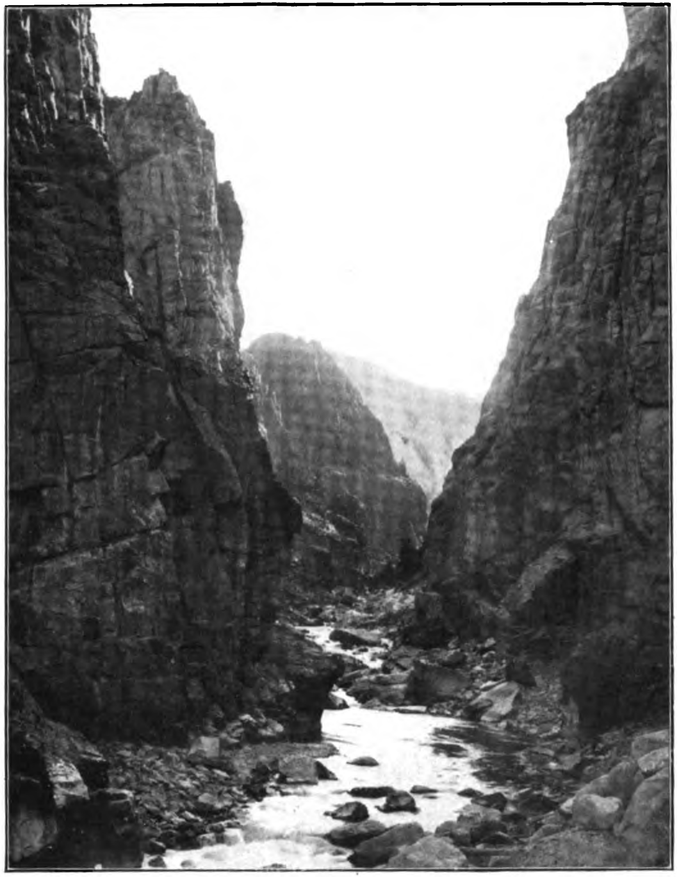
[a] Proposed flow line.

There will be two outlet conduits leaving the reservoir at 10 feet and 60 feet above the bed of the river. The one leaving the reservoir at the elevation of 10 feet will be a tunnel 10 by 10 feet in cross section, 500 feet in length, and will discharge the water, which will be controlled by suitable gates, into the river channel below the dam, from which point it will flow down the channel to the lower diversion point near Corbett, a distance of 16 miles. The upper conduit will be divided into four sections.

Section No. 1 will be in tunnel, and will extend from the reservoir to a ravine cut into the wall of the canyon, where suitable gates will be placed for controlling the water that will be returned to the river at this point. This section of the outlet tunnel will be 6 by 7 feet in cross section, and will have a capacity of 500 second-feet, the water being under pressure from the reservoir.



A. CANYON ROAD ALONG CLIFF, SHOSHONE PROJECT, WYOMING, SHOWING CHARACTER OF ROAD CONSTRUCTION.



B. SHOSHONE CANYON FROM JUST BELOW THE DAM SITE, SHOSHONE PROJECT, WYOMING.

Section No. 1 will be through granite, will require no lining, and its grade will be 2.64 feet per mile.

Section No. 2 of the outlet conduit will be in tunnel, and will extend from the ravine above referred to to the flat at the headquarters camp in Shoshone Canyon, a distance of 2,593 feet. This section will section 8 by 8 feet, a grade of 5.28 feet per mile, and will be lined with concrete. The length of this section will be 8,660 feet, pressurẽ as in section No. 1. Part of this section will be through granite and a part through sandstone, the latter requiring lining.

Section 3 will be an open canal across the flat between sections 2 and 4, and will be 3,000 feet in length.

Section 4 will be a tunnel through limestone and will have a cross section 8 by 8 feet, a grade of 5.28 feet per mile, and will be lined with concrete. The length of this section will be 8,660 feet, which may be cut into shorter lengths for constructive purposes by openings from the tunnel to the wall of the canyon. This section will deliver the water on top of the high bench at the mouth of Shoshone Canyon, at which point the irrigable land begins. At this point the water will enter the main high-line canal, which will have a bottom width of 26 feet, a depth of water of 6 feet, side slopes of 2 to 1, a grade of 1.056 feet per mile, and a capacity of 500 second-feet. The canal will extend from the mouth of Shoshone Canyon to Eaglenest Creek, a distance of 22 miles, in which distance it will irrigate about 20,000 acres. In the above distance there will be 4 drops, at 2 of which power may be developed for pumping water to higher levels. At Eaglenest Creek the canal will be divided into 3 main laterals for the irrigation of 20,000 acres below Eaglenest Creek and north of Ralston station.

LOW-LINE DIVERSION.

As before stated, the low-line conduit will head in Shoshone River 16 miles below the dam, opposite Corbett station. A low diverting dam will be built across the river for the purpose of giving the proper depth of water in the conduit. The first section of the conduit will be a tunnel 3½ miles in length, which will be divided into shorter lengths for constructive purposes by means of short tunnels extending from the main tunnel to the banks of the river. The tunnel will be through sandstone and shale, and will require lining. The water section will be 10 feet by 10 feet, grade 6 feet per mile, and capacity 1,000 second-feet. At the end of the tunnel the water will enter the main low-line canal, which will extend to Frannie station, a distance of 42 miles, irrigating approximately 80,000 acres, 50,000 acres being in the vicinity of the town of Garland. The canal for 10 miles will have a bottom width of 38 feet, a depth of water of 7.5 feet, side slopes of 2 to 1, a grade of 1.056 feet per mile, and a capacity of 1,000 second-feet. From the tenth mile the section will gradually decrease in size.

The proposed canals will furnish water for the reclamation of approximately 125,000 acres of land lying between 4,000 and 5,000 feet above sea level, nearly all of which is first-class land.

FIELD OPERATIONS DURING 1904.

All of the canal and tunnel lines described in the preceding paragraphs have been located and data obtained for a close estimate of the probable cost of construction. One engineering party was engaged upon this work from May until September.

In May a topographic party was organized for making a topographic survey of additional land that may be reclaimed under the project. This land lies between Garland and Frannie, and consists of about 30,000 acres of first-class land. The topographic surveys show that it is feasible to include this land in the project, and plans have been made accordingly.

In July borings at the dam site to determine the depth to bed rock began and are still under way. Seven holes have been driven in gravel and bowlders to a depth of from 30 to 56 feet without striking bed rock, hand drills being used. The bed of the river at the dam site is made up of gravel and bowlders, one of the bowlders encountered being 28 feet through, and the thickness of others varying from that down to a few feet. In October a steam drill was set up and the work of continuing the holes began. Experience on this particular dam site seems to indicate that where large bowlders are encountered it is not economical to go more than 50 feet in depth with hand power drills. Therefore holes were only put down to that depth by hand power, from which depth they will be continued down to bed rock by steam power.[a]

Work of digging test pits along the main conduit began in July and is still under way. The depth of these pits varies from 10 feet along portions of the canal line to 80 feet on tunnel line.

Designs for dam, head-gates, waste gates, drops, and other structures are being made as the general plan of the project develops.

A preliminary classification of the irrigable land has been made.

The construction of a wagon road from the mouth of Shoshone Canyon to the dam site at the head of the canyon, a distance of about 4 miles, is under way, about 3 miles being completed. It is expected that the remaining portion, a large part of which is heavy rock work, will be completed during the coming winter. This road will be extended along the north side of the reservoir, replacing the portion of the road from Cody to the Yellowstone Park that will be covered by water.

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[a] Since the above was written bed rock has been located at a depth of about 60 feet below the bottom of the channel.

An office building of 3 rooms, a lodging house of 9 rooms, and a building for kitchen and dining rooms have been constructed in Shoshone Canyon. Those buildings will be used for headquarters during the construction of the project.

A telephone line 5½ miles in length has been constructed from Cody to headquarters in Shoshone Canyon, and connected with the central office of the Rocky Mountain Bell Telephone Company at Cody.

About 3,000 acres of land that will be flooded by the reservoir is in private ownership, the balance, about 1,600 acres, being public land. Negotiations for the purchase of this land are now under way.

The date for advertising for bids for the construction of the project is dependent on the result of borings now being made at the dam site.

LAKE DE SMET PROJECT.

Investigations of and plans for the development of this project are described in the First and Second Annual Reports of the Reclamation Service.

Continuance of the work on the project is dependent on the results of stream measurements to ascertain the quantity of water available for storage.

RECONNAISSANCE OF STRIP OF SHOSHONE INDIAN RESERVATION IN WYOMING.[a]

The proposed ceded strip of the Shoshone Indian Reservation comprises an area of approximately 2,283 square miles, extending eastward from the North Fork of Wind River on the west to Bighorn River on the east, and northward from Big Wind River to Owl Creek. The irrigable area embraced within these borders is approximately 230,000 acres, lying east of Crow Creek, between Big Wind River and Owl Creek Mountains.

The greater portion of this land is rolling, but can be easily watered. The soil is a sandy loam, warm and fertile, covered with sagebrush. Wheat, oats, rye, barley, alfalfa, potatoes, and garden vegetables are grown very successfully on portions of this strip, and there is no doubt as to the fertility of the soil when properly irrigated. As the land is rolling and has a good drainage, very little of it will be injured by seepage water. Within the area are a number of sand-rock buttes, ranging in size from one-half acre to 160 acres and extending over the entire strip between Big Wind River and Muddy Creek. With the exception of that portion lying within the Big Bend of Big Wind River, comprising 20,000 acres, these buttes make it difficult to determine with any degree of accuracy the amount of irrigable land, and until a topographic map has been made only an approximation is possible. It is believed that the estimate of 230,000 acres, however, is conservative.

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[a] From report by Goyne Drummond.

In the Big Bend of Big Wind River, extending north and west, are about 20,000 acres of fine bottom sagebrush land sloping toward the north and east. North of Muddy Creek, a small stream flowing east through the irrigable land for a distance of 20 miles and then south to Owl Creek Mountains, are 40,000 acres of fine sagebrush land with a slope to the east and south. Between the Big Wind River and Muddy Creek is the largest body of land, 190,000 acres. South and east of Popo Agie River are about 10,000 acres of rolling land sloping to the north and east, which it is believed will be difficult to water.

WATER SUPPLY.

The source of water supply is Big Wind River and its tributaries, which have an approximate drainage area of 2,000 square miles. A measurement of this stream was made on October 19, 1904, at which time the headwaters had begun to freeze and its flow was retarded. The discharge was 406.3 second-feet. This measurement was made at a point about 2 miles above the mouth of Bull Lake Creek and about 7 miles below the point of diversion of the proposed canal.

If the water supply should prove insufficient to irrigate the land without storage reservoirs, there are three reservoir sites above the head of the upper canal, with a combined capacity of 121,000 acre-feet. These are in three lakes, viz: Brooks Lake, 25,000 acre-feet; Torrey Lake, 26,000 acre-feet; and Dinwoody Lake, 70,000 acre-feet. The last-mentioned lake is in the diminished strip of the Shoshone Indian Reservation, but can not be used for storing water for Indian lands, nor will its use in any way be of damage to the Indians if utilized for storing water for the proposed ceded strip. If water is stored in it, it will not flood any grazing land, as the surface area will be increased but little. Dinwoody Creek flows from this lake, and measurements taken on August 29, 1904, show that it had a discharge of 425.6 second-feet.

At Bull Lake, which is also on the diminished strip, a dam 50 feet high could be constructed at little cost which will store 120,000 acre-feet. Bull Lake Creek was measured on August 22, 1904, when it had a discharge of 498.9 second-feet. A portion of the water of this reservoir might be used for watering about 20,000 acres of the diminished strip, but as the bluffs along the river are very high and broken, the cost would be probably $30 per acre. This reservoir will not in any way damage the Indian lands should it be necessary to use it for storage purposes.

The land south and east of Popo Agie River will probably have to be irrigated from stored water, and there are numerous lakes on this stream in the mountains which may be utilized for this purpose. Shoshone Lake, on South Fork of North Fork of Popo Agie River, will have a capacity of 10,000 acre-feet, with a 40-foot dam across its outlet, and the volume of water would be ample to fill it, as the headwaters of this stream are in a region which has heavy snowfall. Big Popo Agie River, below its junction with Little Wind River, on August 17, 1904, had a discharge of 592.3 second-feet. North Fork of Popo Agie River, on August 31, had a discharge of 118.8 second-feet.

HIGH-LINE CANAL.

A survey was made during the forepart of July, 1904, of a high-line canal. Its head is in the southwest corner of sec. 7, T. 4 N., R. 3 W. Its source is in Big Wind River, and the waters stored in the Brooks, Torrey, and Dinwoody lakes can be utilized in this canal if necessary. The course of the canal is easterly, covering the entire strip of irrigable land north of Big Wind River. Its capacity is 1,300 second-feet, its width 50 feet on the bottom, and its slope 1 foot per mile.

This canal line is located on comparatively level ground and extends about 72 miles to cover 40,000 acres of land north of Muddy Creek. Laterals can be constructed from the canal to cover all the land, but it is believed that other canal lines can be taken out at a less cost than the laterals, and owing to the fact that the fall of the country is too great for the slope for canals, it will be necessary to build a number of drops in them. On the high-line canal are 3 drops; the first, at a point 36 miles from the head, has a drop of 86 feet; the second, at 37 miles, a drop of 55 feet; and the third, at 48 miles, a drop of 60 feet. These drops are necessary in order to avoid heavy rock side hill work, but very little land will be lost by them.

Another canal line is proposed in order to avoid carrying the water so far in canals. This is taken from Big Wind River, in sec. 36, T. 3 N., R. 1 W., as shown on the maps, and has very little sidehill work. The low line is taken out of Big Wind River, in sec. 32, T. 2 N., R. 2 E. This is also on good ground for construction, with very little sidehill work, and ground of a character to maintain a canal.

LAND ON THE DIMINISHED STRIP.

Between Little Wind and Popo Agie rivers are about 60,000 acres of irrigable land which will have to be watered from these streams. Storage will be required. These streams for a portion of the irrigation season have water enough, and if the present system of farming by the Indians were continued will always have enough, but if all the irrigable land is once under cultivation the normal flow of the streams will be inadequate for late irrigation.

At the mouth of South Fork in Little Wind River Canyon there is storage for about 16,000 acre-feet, and above the falls are numerous lakes which will doubtless afford storage for all the flood waters required. Meadow Creek, one of the lesser tributaries, has flow sufficient to irrigate about 10,000 acres, and it is thought that this area of irrigable land can be found adjacent to it. This stream, however, sinks in a cave near the mouth of the canyon, and in order to utilize the water it will be necessary to construct a canal 2,000 feet long through a limestone ledge, carrying the stream around the point where it sinks and turning it into the channel below, whence it could be taken out on the land.

On Bighorn River, at the mouth of the canyon in Owl Creek Mountains, is the only reservoir site on this stream. Its capacity can not be determined until a detailed survey has been made. In Sheep Mountain Canyon on Bighorn River is a good site for a dam, but the valley is narrow and the area covered by the water small, so that it is not thought practicable as a reservoir site.

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Zuni Indian Reservation, irrigation on 175
Zuni River, Ariz., conditions on 175

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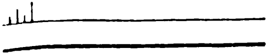

RIVER PROJECT,

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VALLEY PROJECT, COL

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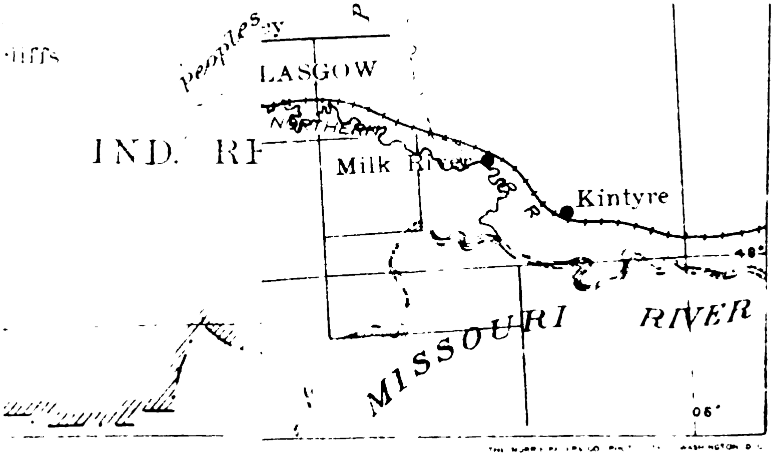
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Peoples
LASGOW
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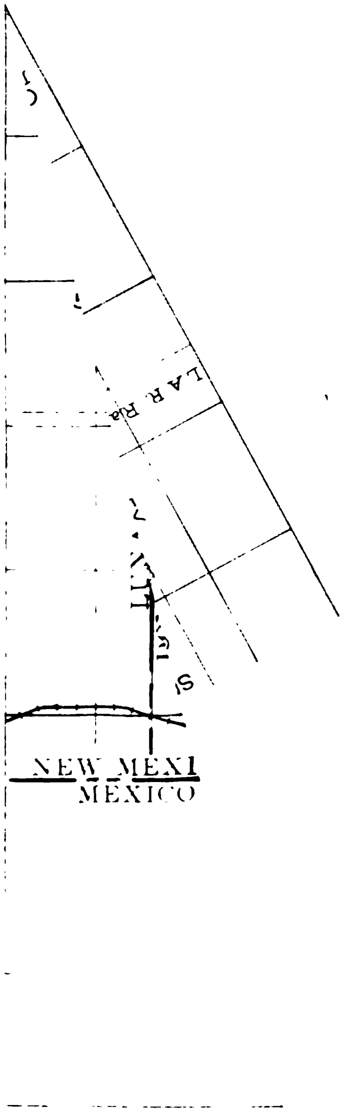
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